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MACHINES, TOOLS AND METHODS OF AUTOMOBILE MANUFACTURE

CONTENTS

49-55 Lafayette Street, New York City

CHAPTER I

ORGANIZATION AND EQUIPMENT OF AN AUTOMOBILE FACTORY*

The Leland, Faulconer & Norton Co., of Detroit, Mich., was formed in 1890 for the purpose of building machine tools and special machinery. Special milling machines, a lathe center grinder, a wet tool grinder, and some special machinery were built. Later the manufacture of wood trimmers for pattern shop use was undertaken; and next, during the development period of the bicycle industry, a line of machinery for making hardened and ground bicycle gears was developed. As the bicycle business declined, the company began building gas engines for motor boats, which were then rapidly rising in popularity. The natural step from the marine to the automobile type of gas engine was made in 1901 to 1902, when the motor now used in the Cadillac car was produced. In 1905 the company was united with the automobile firm building the Cadillac car to form the present Cadillac Motor Car Co. From 1902 until March, 1909, about 21,000 cars had been turned out, 17,000 of which were single cylinder 10 H. P. machines, and the rest four cylinder cars, rated at 30 H. P.

The Plant and Its Organization

The main or Cadillac plant has a double siding connected with the Belt Line Railroad, thus giving ample shipping facilities. The factory buildings are of brick and reinforced concrete construction, lighted by large windows. Heat is supplied by a live steam system. The boiler-room contains three water tube boilers, with room for another if it is needed. Light and power are furnished by electric current supplied by the Detroit Edison Co. Electric driving is used throughout the plant, with motors connected with each line shaft, and occasional installations with direct connected tools. A large compressor furnishes air at 125 pounds pressure for the pneumatic hammers in the frame department, and for use in the various assembling departments, for cleaning parts, running air drills, etc. Five large elevators in fire-proofed brick shafts convey materials and parts between the various floors. An automatic sprinkler system is installed, supplied by four tanks on the roof. These tanks are filled by a large fire pump which operates whenever the level of water in the tanks is reduced. This same system supplies water for lavatory and wash-room use. There are two large wash-rooms, each having 600 bowls and 1,000 lockers.

The old Leland & Faulconer plant comprises a foundry building of brick, steel and glass, supplied with cupolas and a hydraulic jib crane; a pattern shop and pattern storage building; a brass foundry build-

* MACHINERY, March, 1909.

ing; a brick building for the case-hardening department; and a large three story brick building for the power plant and the sheet metal and brass working departments. The building is lighted by both gas and electricity, has a hot-air heating system, and is provided with large wash-rooms on each floor.

The organization of the plant is divided into the following departments: First, the general manager; second, the secretary; third, the sales department; fourth, the advertising department; fifth, the purchasing department; sixth, the time-keeping and cost-keeping department; seventh, the superintendent and his assistants; eighth, the engineering and designing departments, which produce the new models, tools and fixtures, and in conjunction with the experimental department, test the new cars before placing them on the market; ninth, the foremen and their assistants in the forty-four manufacturing departments; and six other special departments, some of which will be mentioned later. While the reader will be most interested in the departments devoted strictly to manufacturing, the work of the engineering and purchasing departments is worthy of some notice.

The designing-room is separate from the general drawing room and is used by the chief engineer and two designers. Suggestions for new designs and improvements in old ones may be made by any one on suitable blanks. They are all considered and passed upon by a mechanical committee, consisting of the general manager, the chief engineer, and the two designers. When approved, such changes are made immediately on the tracings, and new blue-prints are made and sent to the departments concerned in producing those parts. This keeps the blue-prints up-to-date, and avoids loss in the carrying through of parts of obsolete design. A well-organized experimental department is provided, having the necessary apparatus for testing new designs. The work of the general drawing-room includes the detailing of new designs, and the drafting work on the necessary tools, gages, jigs and fixtures needed to produce new parts or models. Filing cabinets are provided for current drawings, as well as for those which are obsolete, of which a full record is kept.

The Purchasing Department, the Stock-rooms and the Gasoline Storage

The purchasing agent has final authority on all matters concerning the actual buying of material used in the cars, and the care of this material until it goes to the machine or assembling departments. Purchasing orders are made out in quadruplicate. One copy goes to the seller, one to the receiving office, one to the bookkeeping department, and one to the file in the purchasing office. Small commercial parts, such as nuts, rivets, etc., are stored in bins in the general stock-room, which also receives the finished and inspected parts turned out by the manufacturing departments. The stock-room record is kept on a card index system, and material is delivered by the stock-keeper only on presentation of a requisition from the foreman of the department where it is to be used. Bulky parts and materials are kept in a large

warehouse, which is also under the care of the purchasing department. A separate stock-room is required for repair parts. These are kept in stock for all models, clear back to the first one placed on the market, and they are replaced as fast as sold out.

The gasoline used in testing the cars is also considered as stock, and a very carefully planned storage system is provided for it. Four cylindrical tanks of 15,000 gallons capacity each are buried in concrete near the siding, with the tops of the tanks about five feet below the street level. They are connected at top and bottom by separate cross piping. The system of storage is such that these tanks are always full of water or gasoline, or both, so that air is always excluded, making explosion impossible. The upper cross pipe permits the free passage of gasoline between the tanks, while the lower pipe performs the same function for the water. A suitable arrangement of automatic valves lets in water as fast as gasoline is removed, or permits the escape of water as gasoline is introduced.

A notable safety provision in the outlet piping for the water positively prevents the escape of gasoline into the sewer. The outlet pipe is formed into a long U-bend, which extends vertically to a depth of 70 feet, inside of an 18-inch casing. From this it returns and discharges through a trap into the sewer. The depth of this bend is such that the column of water on the outlet side will balance a column of gasoline having a height corresponding to the head obtainable from a tank car on a grade 5 feet higher than the present siding. The water thus furnishes a permanent seal against the discharge of gasoline.

The distribution of the gasoline is also carefully safe-guarded. It is supplied to the various testing rooms and to the factory garage through piping from the storage system. It is retailed by Bowser registering pumps which are kept locked when not in use. As a further safeguard, all the piping is enclosed in concrete, and the whole system is so arranged that it may be flooded with water to a depth of five feet in case of fire in any building which might later be built over it.

Tool and Tool Supply Departments

The tool department is located on the top floor and at the north side of the building, where the best light is obtainable. It is devoted to the manufacture of the jigs and fixtures and many of the gages employed in the factory. The equipment consists largely of Reed and Hendey & Norton lathes, Hendey shapers, Brown & Sharpe milling machines, and Brown & Sharpe universal and surface grinders. The high degree of interchangeability required in the product demands a high standard of workmanship in this department. At the time Fig. 1 was taken, some manufacturing was being done here. A wire enclosure at the right contains the tool inspecting department. The tool steel stock and tool grinding rooms are at the further end of the picture.

The tool supply department is closely allied with the tool-room. Its work is principally that of caring for, sharpening and recording the various jigs, fixtures and cutting tools. All these tools are looked

out for by a card index system, which shows where they are used, and what repairs, if any, have been necessary. This department orders all the small commercial tools, and keeps a debit account with each branch tool-room for the supplies furnished it, giving credit for all tools worn out in legitimate use or broken in unavoidable accidents. A perpetual inventory is thus kept of all the special and commercial tools kept on hand. A card index inventory of the machine tools is kept in the purchasing department.

Forge, Foundry and Sheet Metal Departments

It will not be possible to more than briefly mention that part of the equipment of the forty-four manufacturing departments which is concerned with the actual work on the parts. The blacksmith shop is small, owing to the extensive use of drop forgings, but it is finely

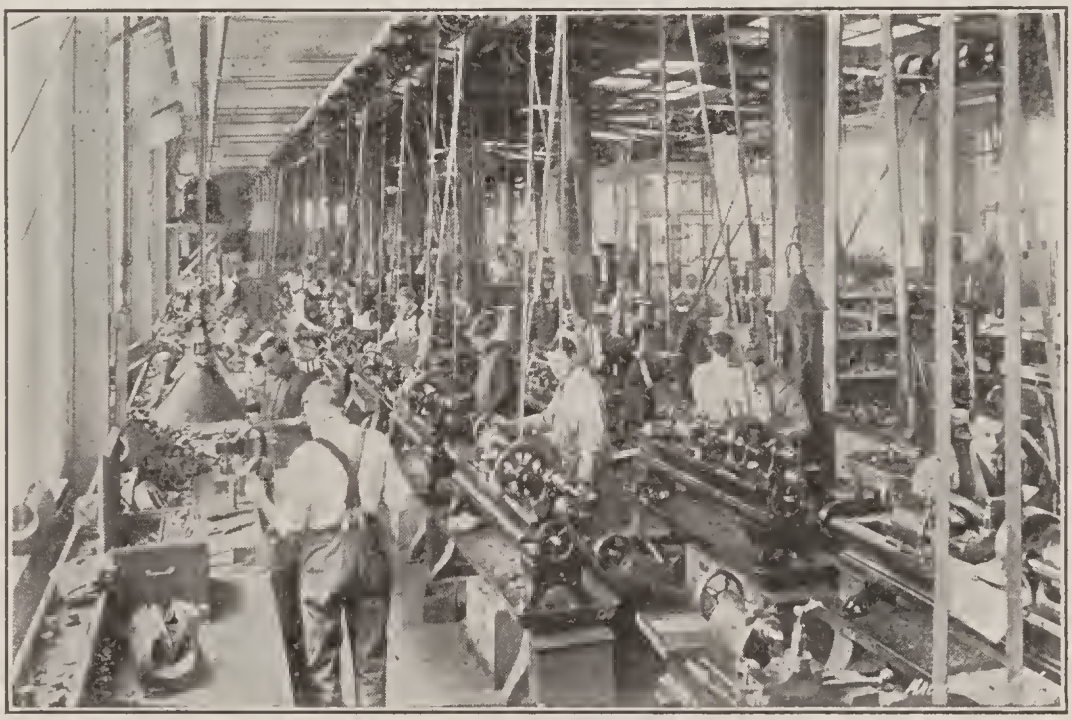

Fig. 1. A Partial View of the Tool-making Department

fitted up with Buffalo down-draft forges, a tool forge with a coke magazine, gas furnaces, water jacketed dipping tanks, and an electric welding machine. The bulk of the work consists of tool dressing, and the making of forgings for jigs and fixtures and for special car equipment. The case-hardening department has ten large Frankfort gas furnaces equipped with pyrometers, connected by a switch board with a galvanometer graduated to degrees Fahrenheit. Oil and water dipping tanks with steam and cooling water jackets are provided. These are piped to a steam pump to give positive circulation. Square and oblong pots are used for small machine parts, while round pots with central holes, to insure uniform heat, are used for the large rear axle bevel gear.

The iron foundry is provided with a large and a small cupola. The latter is used largely for heats of a special nature. The most approved methods for testing and chemical analysis are employed to keep track of the output. This is necessitated by the fact that the foundry furnishes castings for other motor car builders besides the

Cadillac Company. The brass foundry furnishes the necessary castings for the bronze bushings, carburetor and lubricator parts, small valves and fittings, etc. These are finished in the brass machine shop, which is equipped with forty Warner & Swasey screw machines, besides several Fox lathes, drill presses, milling machines and several special lathes. All the lubricators, gasoline valves, carburetors and bearings used are produced here.

In the sheet metal department are made the vertical tubular radiators, gasoline tanks, dashes, fenders, etc., as well as small punchings, such as washers, clips, etc. The press-room has a complete equipment, ranging from foot presses up to 20-ton power presses, capable of cutting and forming parts up to 36 by 48 inches. Gas furnaces are used for heating the soldering irons and work when assembling the radiators. The radiators and tanks are tested by compressed air, while

Fig. 2. The Chassis Drilling and Milling Departments

submerged in water. The frame department is equipped with gas furnaces and pneumatic hammers for riveting and heading.

Equipment of the Machine Departments

For convenience in handling the work, all the engine parts are drilled and milled in two separate departments in one large room, while the similar operations on the chassis parts are performed in another room, which is shown in part in Fig. 2. The equipment of this department includes a large number of Cincinnati drill presses, Cincinnati and Brown & Sharpe milling machines, and a Beaman & Smith cylinder boring machine, arranged for handling transmission cases and axle housings. The engraving shows the large use of multiple spindle drills, quick change drill sockets and jigs.

The equipment of the motor drilling department is somewhat similar, ranging from a sensitive bench drill to a 24-spindle motor-driven Baush machine. This is used in drilling the 24 holes for studs, cap screws, etc., in the lower half of the motor frame. These holes are all drilled

at one time, and have to accurately match similar holes in the upper half. This, it will be seen, requires a high grade of workmanship. The milling department for motor parts employs several Whitney hand millers, Brown & Sharpe horizontal millers of various sizes, several vertical machines of the same make, and six heavy motor-driven Cincinnati machines. There are also to be found here two milling machines built by Leland & Faulconer, which are unusual in that the table has longitudinal and cross feeds only, the vertical adjustment being applied to the spindle. High-speed steel inserted tooth cutters are in general use.

The screw machine department is one of the largest in the factory, occupying a floor space of 80 by 200 feet, and containing 62 machines, exclusive of the tool grinders. Brown & Sharpe, National, Acme, Davenport and Cleveland machines are used for making cap screws, nuts, studs and other parts up to one inch in diameter. Gridley machines are employed for larger work. Jones & Lamson flat turret lathes are used for shafts, spindles and some gear blanks. The Potter & Johnston automatic machine is employed for much of the chucking work in combination with the Gisholt and Steinle machines, which are used mostly for machining clutch and gear mounts. A group of Bardons & Oliver machines are used on certain engine parts, which have to be held in face-plate fixtures and finished largely by hand labor. The larger Acme machines are direct connected.

While most of the round parts are finished complete on the screw machine, a lathe department is necessary for some work which has to be turned on arbors. Fly-wheels and some long axle shafts are also finished here. The equipment includes Reed lathes, a Bullard boring machine for finishing fly-wheels, and two Beaman & Smith double-spindle horizontal boring machines for roughing out the cylinders. The latter are provided with turntable fixtures, so that two cylinders may be set up while two others are being bored. After the cylinders are roughed out, they are tested under hydraulic pressure and sent to the grinding department.

The grinding department finishes practically every round part on the car except the crank-shaft, which comes finished from a firm making a specialty of that work. Heavy Norton and Brown & Sharpe grinders are used for finishing long parts. Medium sized Landis and Brown & Sharpe grinders take care of work up to 3 inches in diameter and 8 inches long. Special Brown & Sharpe and Heald grinders are used for finishing the cylinders, which are held exactly as they will be on the assembled engine, so that clamping strains are duplicated. The pistons are finished in one of the heavy Norton machines. The group of Heald machines is used exclusively on internal work, and an equipment of face grinders finishes the washers and flat disks used in the cars. The square shafts which carry the sliding members of the transmission are ground to size on a group of Brown & Sharpe surface machines, fitted with suitable index fixtures. In contrast to the heavy Norton grinders with their 24-inch wheels, is a bench grinder

purchased from the Waltham Watch Tool Co., for finishing internal ball races. This little machine uses a wheel about the size of a five-cent piece, and may be set to grind to a radius of 1/8 inch. Careful attention is given to providing suitable racks for ground work to avoid injury in handling.

In Fig. 3 is seen a partial view of the gear-cutting department. A Gleason bevel gear generating machine is here shown at work cutting a rear axle gear. The complete equipment includes thirty standard machines, and four others of special design, besides four testing machines. The list includes fifteen Brown & Sharpe automatic gear cutters, one large Gould & Eberhardt machine, two Fellows gear shapers for internal gears, one Bilgram and three Gleason bevel gear planers, two imported French machines for special pinion work, and a Pratt & Whitney worm milling machine. One of the testing machines, that

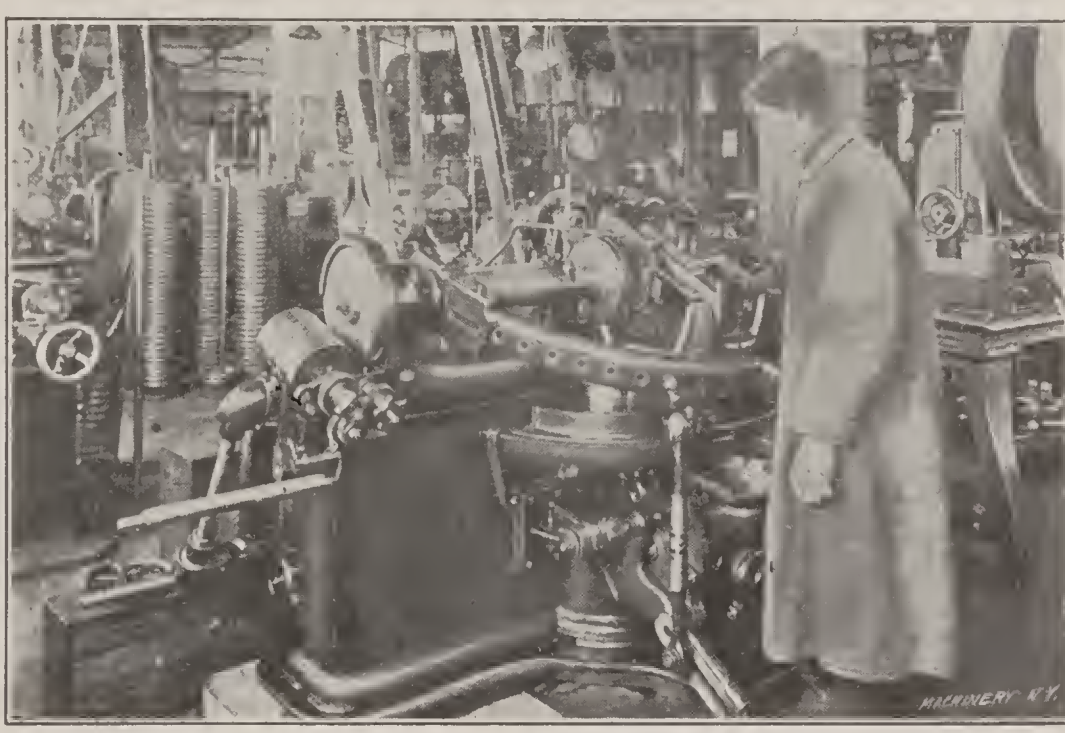

Fig. 3. A Corner of the Gear-cutting Room

for bevel gears, is seen at the extreme right of Fig. 3. The testing machine for spur gears is provided with a vernier scale for reading center distances to thousandths of an inch.

Inspection and Assembling Departments

The inspection department consists of a chief inspector and his foremen, and the men under them, who together form a corps of over one hundred men. These men inspect commercial parts as they go through the receiving department, the output of each manufacturing department as it goes to the assembling, the final assembling of the parts in the chassis, and the finish of the completed machine on both the mechanism and the body. The inspectors are furnished with all necessary appliances for doing this work accurately. Drop forgings are examined for visible flaws, and sounded for invisible ones. Springs are tested on machines especially built for the purpose. Every machine department has its inspection bench, provided with the necessary plug and snap gages for the entire range of its output. Microm-

eter calipers up to the 6-inch size are in general use. Thread micrometers are used in place of ring thread gages wherever possible. For testing turned and bored parts for concentricity, Brown & Sharpe testing centers and indicators are used. Suitable surface plates, V-blocks and height gages are provided. The inspectors in the grinding department are furnished with strong reading glasses for use on certain work. These inspectors are outside the jurisdiction of the other department-heads, and have full authority to throw out all parts and materials not up to the standard.

The work of assembling is divided between several gangs, each of which does it own particular work. One group of assemblers scrapes the crank-shaft bearings to fit, and "runs them in" by a belt on the fly-wheel. Another assembles the cam-shaft members. Still another assembles the piston, its rings, pins, connecting-rod and bearings.

Fig. 4. The Four-cylinder Engine Assembling Department

while the "cylinder gang" assembles the cylinder and cylinder head and copper water jacket. The final assembling is then done on stands as shown in Fig. 4. This consists merely in bolting the various parts together, setting the cam gears (which are marked in a jig), timing the valves, adjusting the bearings, and testing the water connections. The points of valve opening and closing are marked on the rim of the fly-wheel, and a fixed pointer shows the central position.

The Testing Department and Its Equipment

From the assembling room the engines are taken to the testing department, where they are placed on iron stands and connected with the gasoline and water supplies, and to the electrical connections for the ignition, as shown plainly in Fig. 5. The engines are run at moderate speed until they get down to work, when the speed is gradually brought up to the maximum. A brake-horsepower test of each engine is made, and those which fail to come up to the requirements are returned to the assembling department for reconstruction. As a check

on this test, stock engines are sent to the experimental department at regular intervals, and tested there by connection with a dynamo fitted with suitable electrical measuring instruments. After the testing the engines go into stock, or to the chassis assembling department.

All the parts necessary for the completed chassis are brought to this assembling department. The order of assembling is as follows: The frames are first laid on horses and the mechanism dust shield is put on. The springs and axles are next attached, and then the engine and transmission gearing are set and lined up. The engine is supported at three points, and is connected by a universal sliding joint with the transmission gearing, thus permitting "weaving" of the frame without danger of disalignment. The universal joint between the transmission and the differential gearing is practically straight when the car is loaded, and runs at a very slight angle when the car is light. The

Fig. 5. Testing the Four-cylinder Engines

exhaust pipe and muffler are next connected, and then the controlling and brake levers and the pedals. The radiator and water connections come next, followed by the steering gear. The placing of the mahogany dash in position permits the mounting of the electrical apparatus; and the bolting on of the gasoline tank and its connections completes the chassis, except for the wheels and tires. An old set of these are put on the car in the assembling department, to be used for the road test. The method of assembling is practically the same for the single cylinder car.

Two separate testing departments are provided—one for the single-cylinder cars, and the other for the four-cylinder cars. The former were given road tests for the first two years of their manufacture, until all the weak points in the construction had been eliminated. The testing room shown in Fig. 6 was then built, and the cars have since been tested here. Fifteen stands are provided. The rear wheels rest on a pair of 48-inch pulleys, mounted on a shaft which carries a fan

about 72 inches in diameter by 36 inches wide, projecting through the floor in the sheet iron casing shown. In addition to the resistance thus offered by the fan, a brake is mounted on the shaft between the pulleys, controlled by the hand-wheel on the stand shown projecting through the floor at the rear of each machine. By this means it is possible to work the engine against any desired resistance, even to the extent of stalling it. The chassis are held by padded hooks, fastened by ropes or chains to the brake wheel stands. The blast of air produced by each fan is led through a sheet metal conduit and directed against the radiator of the engine, thus giving the same cooling effect that would be experienced at corresponding speeds on the road on a still day. The speed in miles per hour is read from Schaffer & Budenburg tachometers.

Fig. 6. The Single-cylinder Chassis Testing Stand, arranged for Fan and Brake Resistance

The four-cylinder testing stands are similar in principle, though somewhat differently arranged, as the fans are placed beneath the front of the machine, being connected with the driving shafts by sprockets and chains. After being run here a sufficient time to make sure of their adjustment and running condition, temporary bodies are placed on the chassis and each car given a thorough test by reliable men on the country roads outside the city. After this has been done to the satisfaction of the foreman of the department, the testing body is removed and the chassis is washed successively in water and gasoline, and dried by an air jet.

Finishing

The painting and finishing of the chassis, bodies and wheels is done in separate departments. The bodies receive one coat of rough filler, and fifteen more coats of filler color and varnish, before completion. A view of the trimming department for the bodies is shown in Fig. 7. Fenders, hoods, brackets, etc., are enameled and baked. Fig. 8 shows

some of the pipe frame trucks used to hold these sheet metal parts during the baking.

The chassis, bodies, hoods, fenders, etc., finally go to the large finishing-room on the ground floor, where the final assembling and test-

Fig. 7. The Body Trimming Department

ing of the complete car is done. Each complete car is driven out by a final inspector to make sure that all adjustments are correct. Before shipping, a detailed record is made of each car, beginning with the motor number, and giving the dates of motor assembling, motor

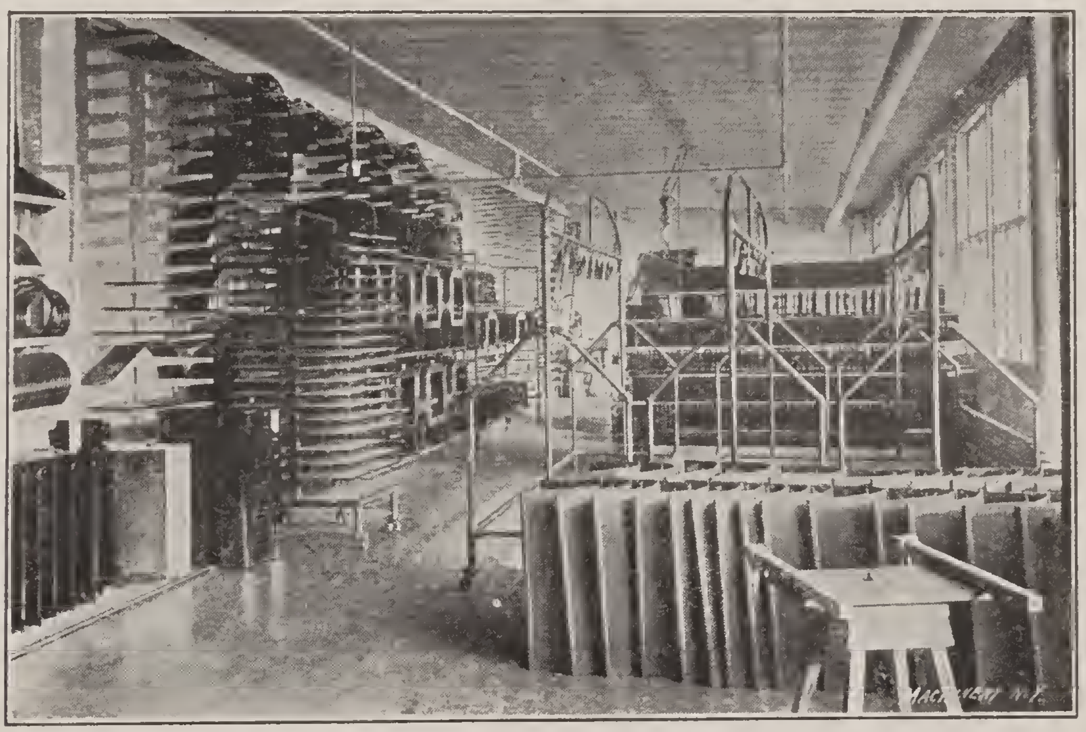

Fig. 8. Storage of Enamelled Parts, showing Wheeled Stands used in the Baking Ovens

testing, all the various painting, finishing and shipping dates, together with any information of a special kind; such as size and color of body, etc. This record has been found of the greatest assistance to the repair order department in filling poorly written orders.

Interchangeability

In connection with this subject of repair orders, mention should be made of the high degree of interchangeability attained by the Cadillac Co. This was illustrated by a test made in March, 1908, by a committee of the Royal Auto Club of England, who selected by lot three Cadillac cars of the same 10-horsepower model, disassembled them under the eyes of an inspector of their own appointment, placed the disassembled parts (721 from each car) in a pile, and mixed them up indiscriminately; 81 parts were then taken out and replaced by 81 repair parts from stock. The cars were thereupon reassembled from this mixed pile by the use of wrenches, screw-drivers, etc., but without the use of scrapers, files or even emery cloth. Only one part, a cotter pin, was injured in reassembling. These three heterogeneously reassembled cars were each given a 500-mile reliability run on the Brooklands track, at an average speed of 33 to 34 miles per hour, without developing the slightest defect.

CHAPTER II

MACHINES AND TOOLS FOR AUTOMOBILE MANUFACTURE*

The Cadillac Engine

In order to make clear the manufacturing operations which will be referred to in the following, a brief description of the Cadillac engine will here be given. The first automobile made by the Cadillac Motor Car Co., of Detroit, Mich., in 1902, was a runabout containing a 10

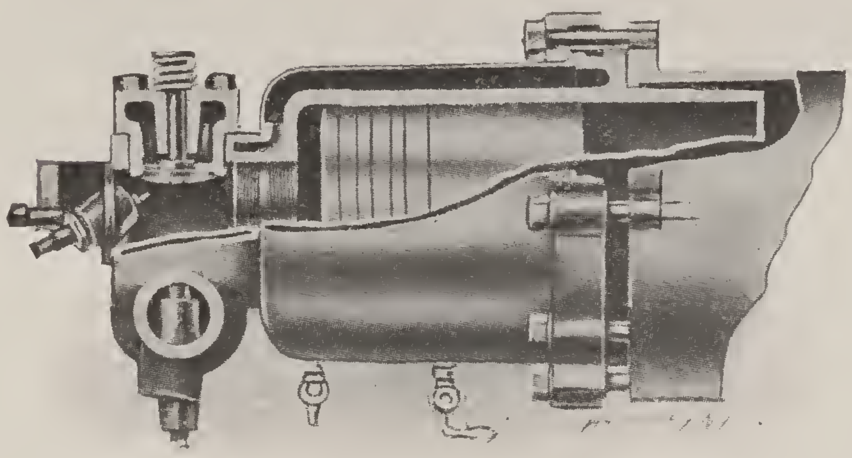

Fig. 9. Section through Cylinder showing the Water Jacket Construction

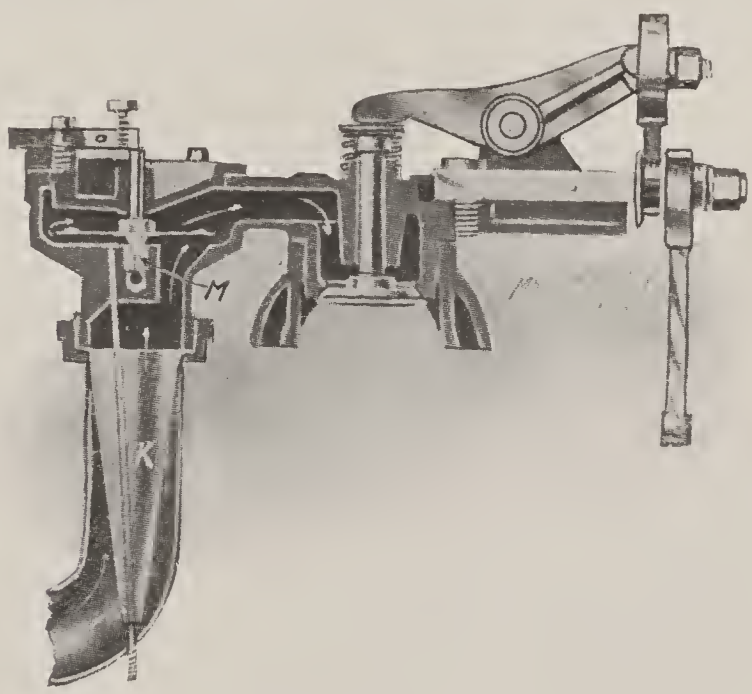

Fig. 10. The Cadillac Carburetor

H. P., single cylinder, four cycle, horizontal engine, of 5-inch bore by 5-inch stroke. This engine was found to be so satisfactory that it has been retained practically unchanged up to the present time, and its general features have been adopted, so far as possible, for

* MACHINERY, March and June, 1909.

the vertical four-cylinder engines of the 30 H. P. machine. A number of original features were employed on this engine which have proved their value in actual practice. One of the most interesting of these is the cylinder construction, best seen in Fig. 9. This cylinder, which is a fine-grained gray iron casting, has a flange near the forward end, which enters and fits a bored and faced seat in the frame. The copper water jacket slips over the cylinder, and is flanged to match

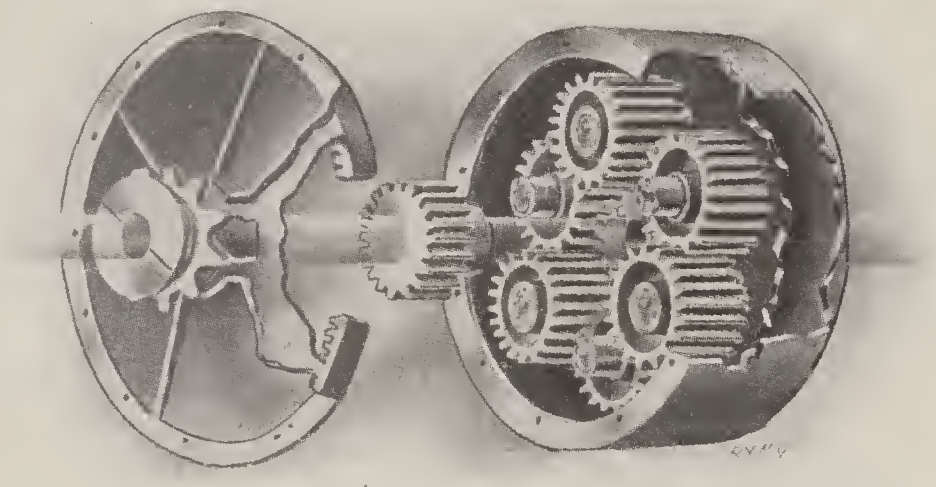

Fig. 11. Planetary Transmission used on the Single-cylinder Engine

its outer face. Both it and the cylinder are held in place by a ring which passes around the outside of the copper jacket, and is tightened down by the studs shown screwed into the frame. In this way the copper jacket forms its own gasket. The cylinder head or valve chamber is held in place by a hollow steel nut (or nipple, rather) which is threaded externally right- and left-hand, and screws into

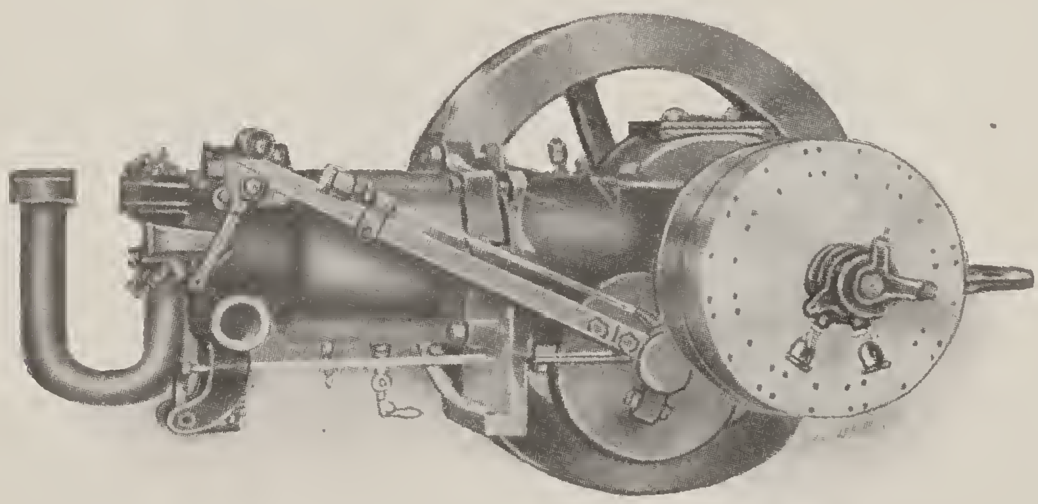

Fig. 12. The 10 H. P. Engine of the Single-cylinder Car

both the cylinder and the valve chamber. The upper end of the copper jacket is clamped between the two, and thus serves for a gasket at this joint also, forming the only packing needed. Parts are kept in alignment by a dowel, and suitable openings connect the jacket space of the cylinder and the head. Among the advantages of this construction over the usual cored jacket are lighter weight, greater water space, more uniform thickness of cylinder walls, facility in

cleaning the jacket space, elimination of trouble from freezing the cooling water, and low repair cost for broken parts.

The exhaust valve is placed in the cylinder head with its axis vertical, and it is operated from the cam shaft by a push-rod and bell-crank. The inlet valve is of the inverted type, located directly above

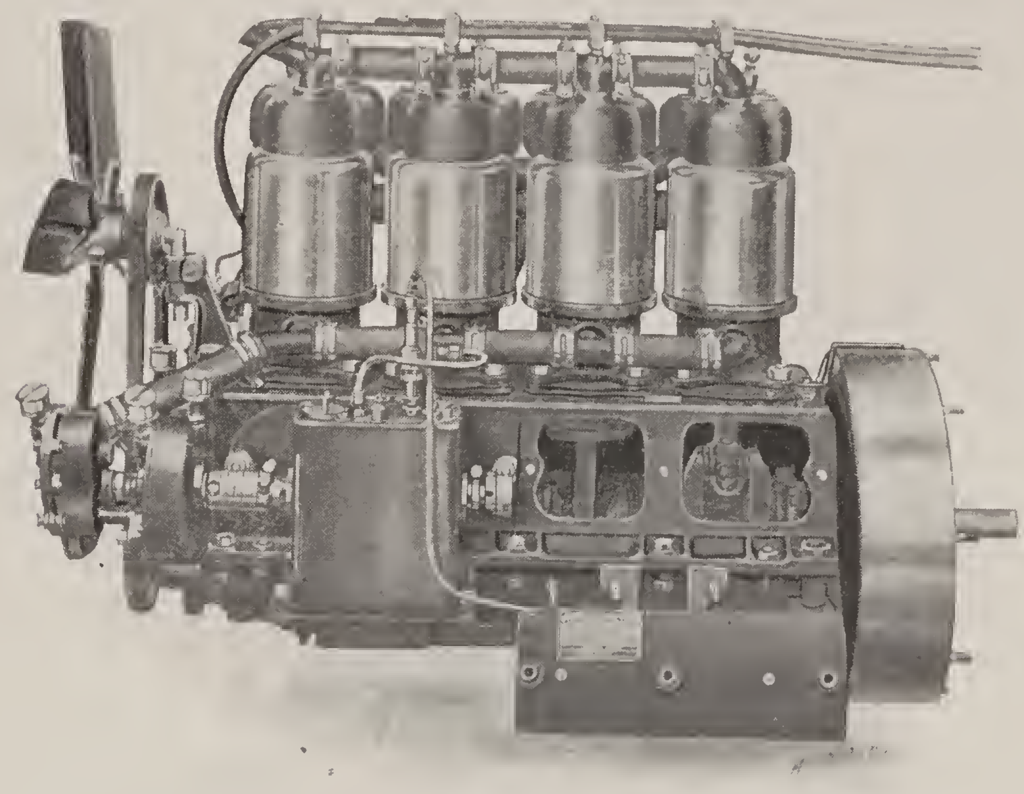

Fig. 13. Left Side of Cadillac 30-horsepower Engine

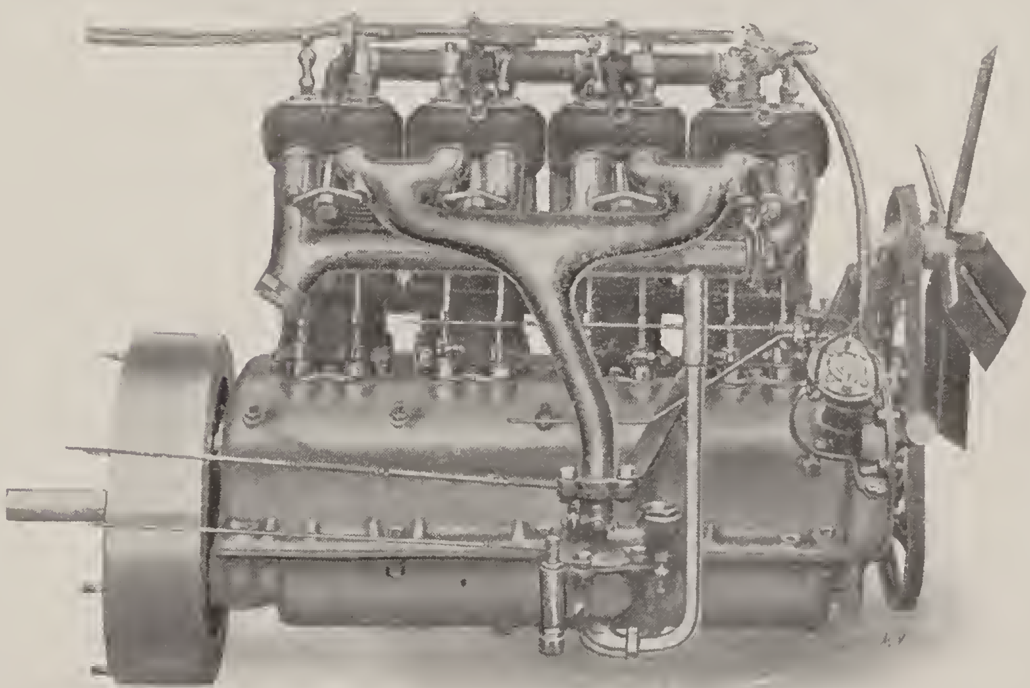

Fig. 14. Right Side of the Engine, showing Carburetor, Commutator, etc.

the exhaust valve. It is operated by a lever with a roller on its outer end which, in turn, is actuated by a push rod riding on a roller mounted on one arm of a short lever. The push-rod is connected with an eccentric on the cam shaft. The lever on which it rides is under the control of the driver, so that the timing of the valve and

the amount of lift may be varied according to the work required. The throttling is thus effected by the inlet valve gear. The carburetor (shown in Fig. 10) is formed in one piece with the inlet valve mechanism. As may be seen, the inrush of air lifts valve *M* and allows the escape of the oil, which falls into the wire mesh basket *K*, where it is vaporized. The lift of the valve may be regulated to give the desired richness of mixture.

The motor frame is made in three parts—the frame proper, and the top and bottom plates. The main shaft, which is offset, is a nickel steel, center-crank forging, finished all over by grinding. It is carried in babbitt lined bronze bearings, fitted in bored and reamed seats in the motor frame. These are held in place by cap plates, which can be adjusted without opening the motor. The cam-shaft is

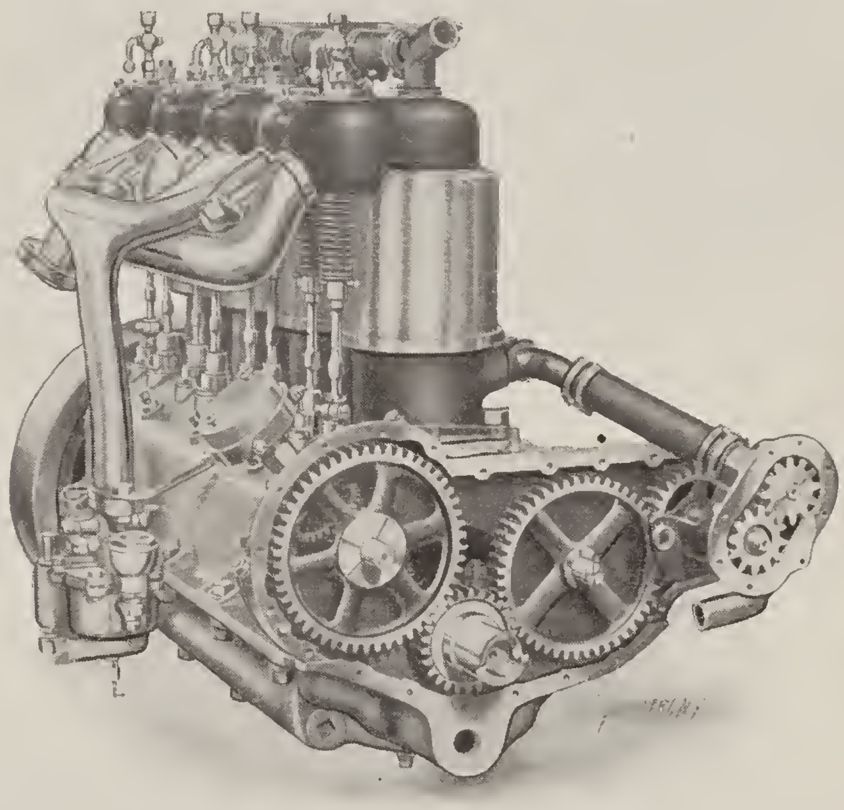

Fig. 15. Front View of the Four-cylinder Engine

carried in bronze bushings inserted in the bottom plate. This plate and the cam-shaft may be removed at any time without disturbing the crank-shaft.

The transmission of the 10 H. P. machine is of the planetary type, providing for two speeds forward and a slow reverse. As shown in Fig. 11, the gearing is all enclosed in an oil-tight casing. On the high-speed forward gear the whole transmission revolves as a unit. The driving pinion is of 40-point carbon steel and is case-hardened, as are also the idler pinions, which have bronze bushings pressed into them after hardening, and run on hardened and ground pins pressed into the gear case. Power is transmitted to the rear axle sprocket by a Whitney roller chain. An assembled view of the engine is shown in Fig. 12.

The later vertical four-cylinder engine for the 30 H. P. machine is shown in Figs. 13 to 19 inclusive. This engine has been built, as

far as practicable, on the lines of the horizontal machine. As may be seen in Fig. 17, the same arrangement is used for clamping together the cylinder, the copper jacket and the cylinder head, although a somewhat different joint is used at the lower end of the jacket. In this engine also the crank-shaft is offset; the construction of the crank

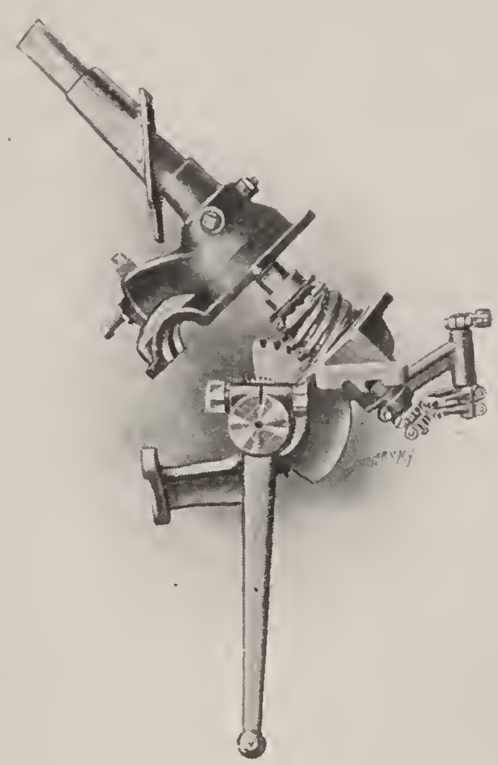

Fig. 16. The Cadillac Steering Gear

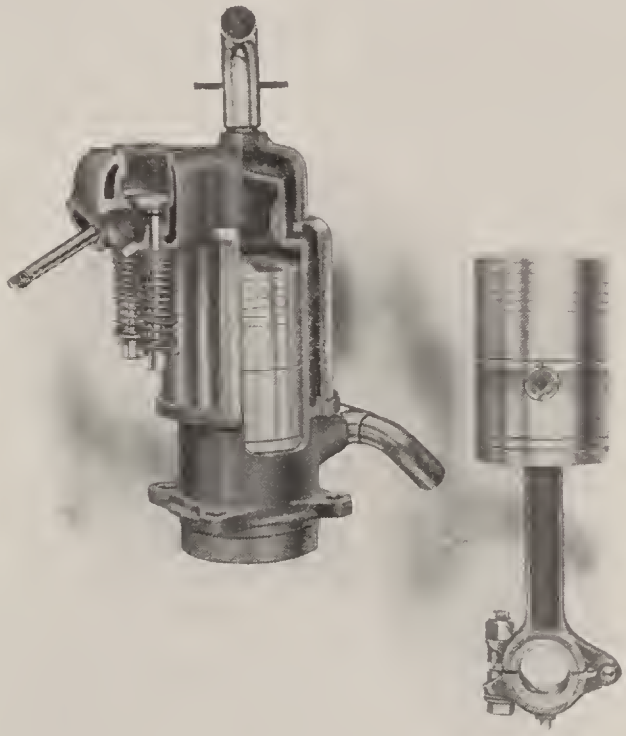

Fig. 17. The Cylinder and Piston

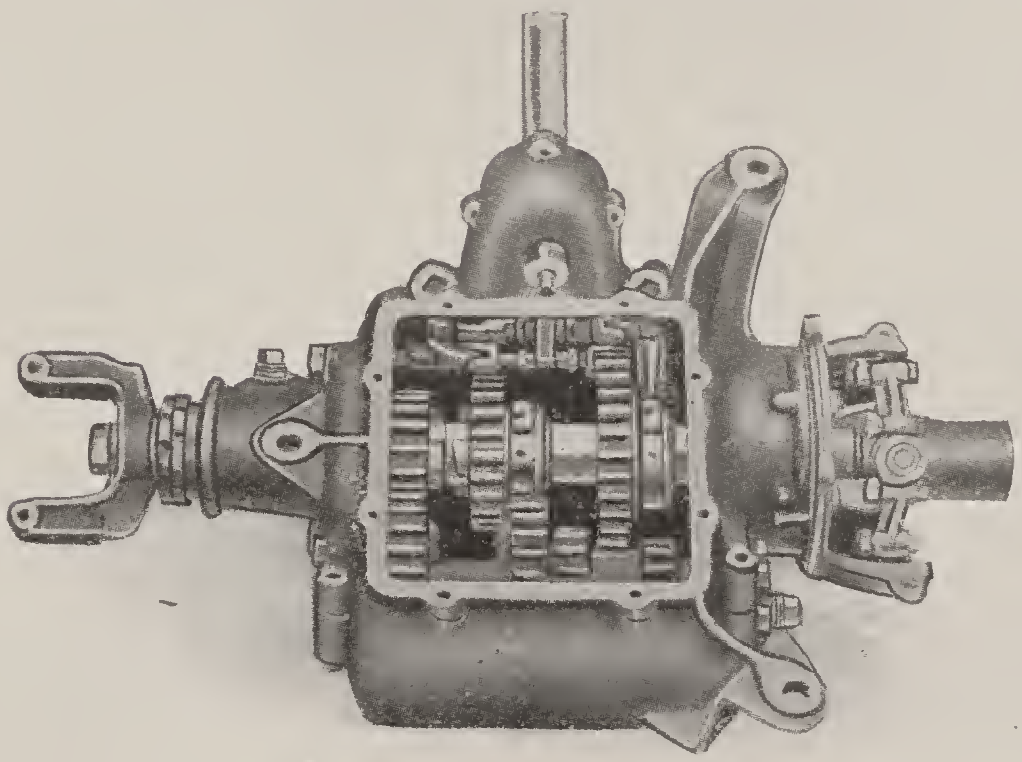

Fig. 18. Selective Type Sliding Gear Transmission

case and base is different, of course, as shown in Fig. 19. A leather-faced cone clutch in the fly-wheel transmits power to the sliding gear transmission (see Fig. 18) which gives three speeds forward and one reverse. The gears and shafts are of oil-treated chrome-nickel steel, and are carried on ball bearings. The gear case is oil-tight, as is also the universal joint housing and the rear axle casing.

The rear axle carries an oil-treated chrome-nickel steel bevel gear and pinion, and the gear mounts are adjustable for wear of the teeth. The steering gear (see Fig. 16) is of the worm and sector type, treated in the same ways as the transmission and differential gearing.

Machines and Tools for Automobile Manufacture

Upon first thought the design and construction of tools and jigs for automobile manufacture may not appear to present any problems radically different from those involved in the manufacture of any other power producing and transmitting machinery; but after a thorough consideration of the conditions under which a motor car necessarily operates, the importance of a standardized, interchangeable, simple and strong construction is realized. As one of the requirements of a car is maximum power with minimum weight, the use of nickel and other steel alloys is required, which, in turn, necessitates the use of high-speed steel in the machine tools. As an automobile engine is

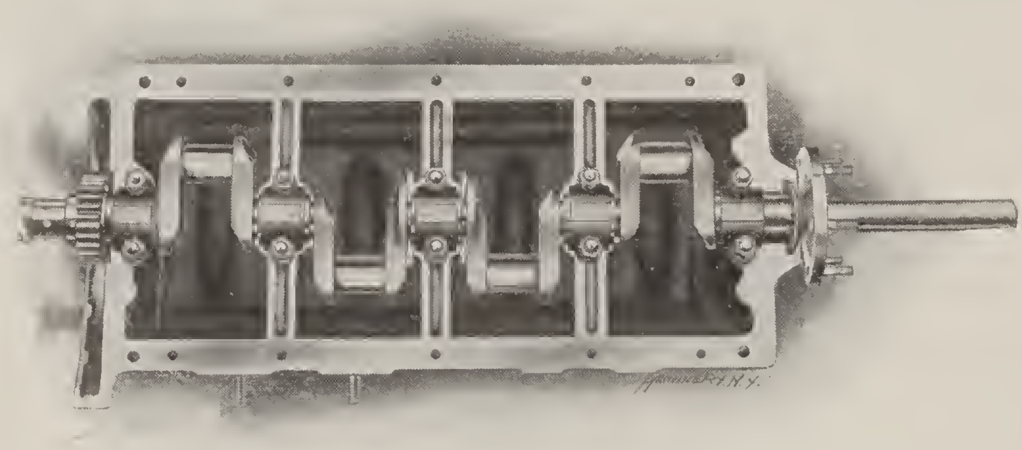

Fig. 19. Top View of Motor Case and Crank-shaft

necessarily a high-speed engine, the provisions for adjustment of wearing parts and the cheap replacement of them when worn out, are of primary importance.

As the great majority of automobile owners are not mechanically inclined and wish the greatest amount of service with the least possible attention to their cars, the necessity of simple and reliable construction is apparent; and, as the motor car is forced by road conditions to do its hardest work on the poorest roads (which are usually farthest from the best repair facilities), under which conditions breakages are most likely to occur, the advantages of interchangeable construction, the parts of which are so designed that they can *not* be incorrectly assembled, are apparent, especially when road repairs must be made by men not thoroughly familiar with the construction of all cars. These are facts that the motor car designer must have seriously in mind, and which must reflect themselves to some extent in the tool design.

It is the purpose of this chapter to show how these ideas are carried out in practice, in the factory of the Cadillac Motor Car Company, and, while space permits showing only a few of the several

thousand special tools, jigs and fixtures, it is thought that those shown will iillustrate the care taken to secure absolute interchangeability and perfect alignment of parts. As the construction of the motor includes some very interesting tools, these together with some testings jigs are shown and described.

Engine Frames

As the engine frame is in two parts, divided horizontally at the shaft center, accurate milling and drilling is required. Heavy Brown

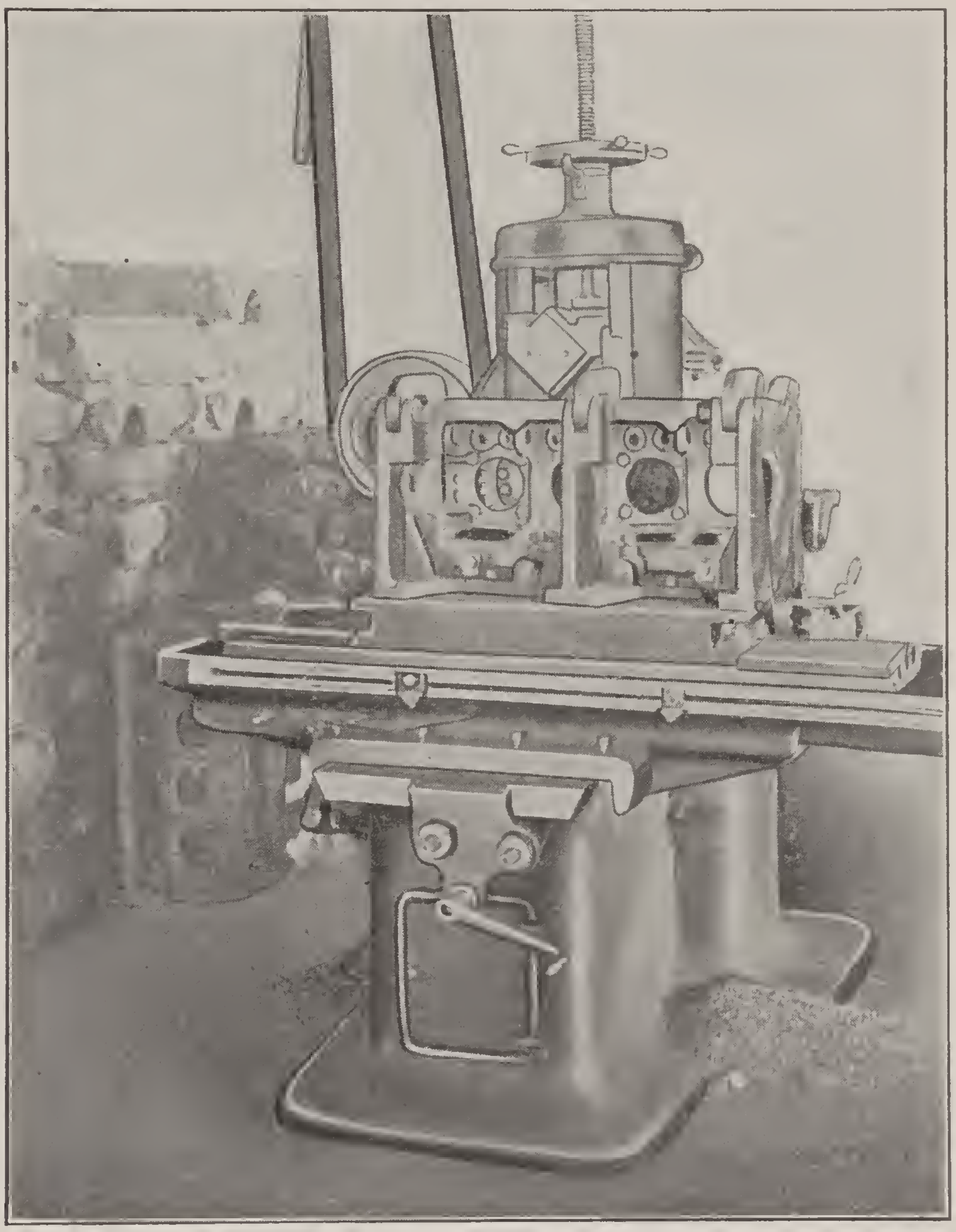

Fig. 20. Milling Engine Frames

& Sharpe, Cincinnati, and Leland & Faulconer machines are fitted with heavy jigs, and large inserted tooth cutters are used on this work. Fig. 20 illustrates the L. & F. machine milling the top face of the engine frame where the cylinders bolt on. This machine is very satisfactory for manufacturing, as the low table permits rapid handling of work, and its heavy construction, large bearing surfaces and all geared feeds and speeds provide for heavy and rapid cutting.

Fig. 21 shows the method of boring the seats for the cylinders in the engine frame. This operation follows that shown in Fig. 20. The cutter heads have a floating drive and are centered by the ground pilots entering inserted bushings in the jig bosses. The whole jig slides forward, and back against a stop to facilitate inserting and removing the work.

Fig. 22 shows the lower half of the crank-case (shown in Fig. 19 with crank-shaft in place) clamped in the jig for drilling 24 holes for

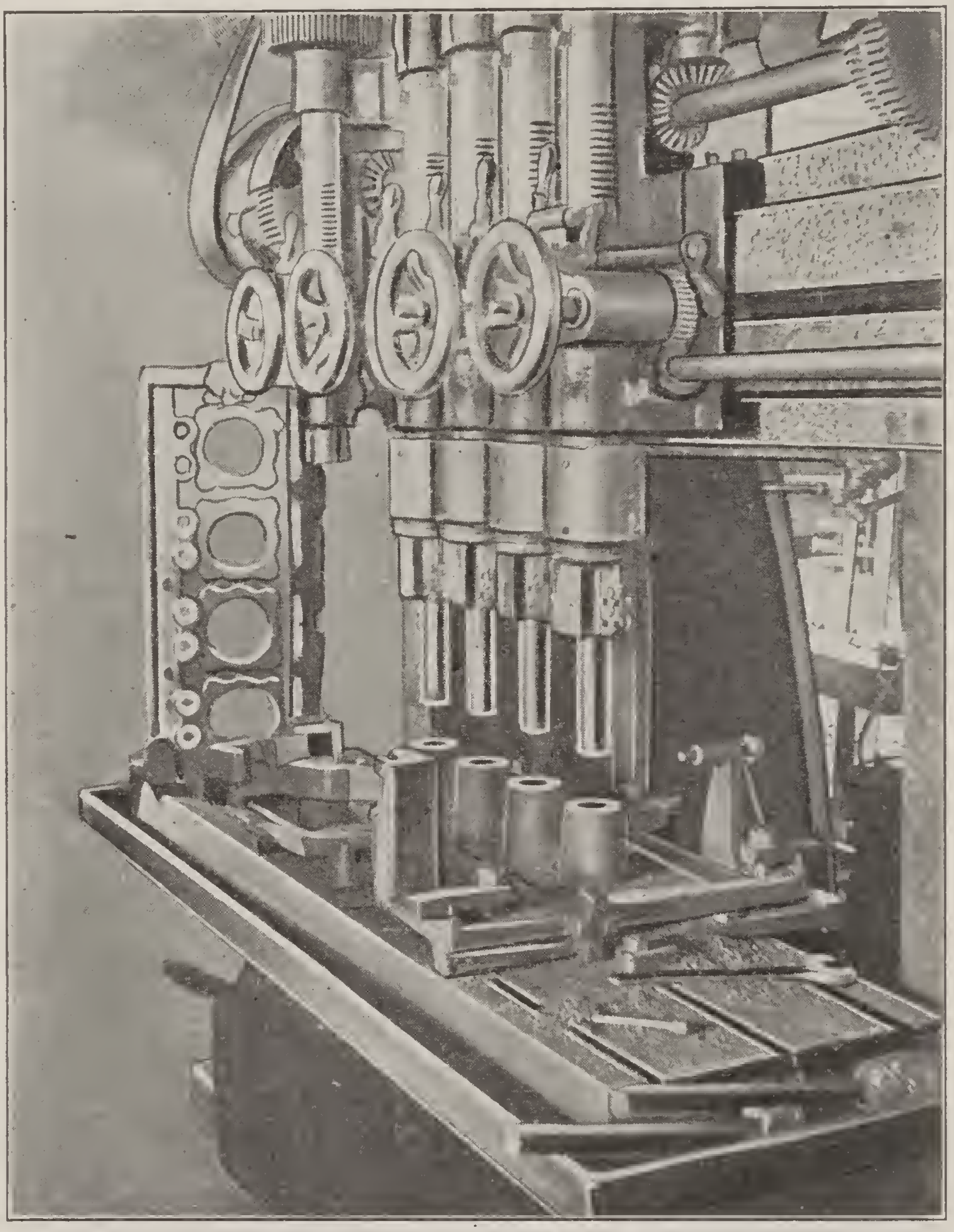

Fig. 21. Machine for Boring Frames

studs and cap-screws. The 24-spindle Baush machine drills these holes in about two minutes, including inserting and removing the work. A similar style of jig is provided for the upper half of the crank-case, which has 18 holes to be drilled in the lower face.

Fig. 23 shows the jig provided for boring the cam-shaft bearing seats in the upper half of the crank-case. These seats are indicated by the letter *A*, and are a very close fit for the five bronze bearings which carry the cam-shaft. The work locates over the two large

bosses in the center of the jig, and rests on hardened and ground plugs inserted in the base. The swing clamps shown bear directly over the plugs. The boring tool, which is driven by a face-plate fixture, is seen projecting through one of the guides. The B. & S. plug gage seen on the lathe carriage, allows only 0.002-inch variation in the size of the holes. A similar type of jig (not shown) is used for boring the main bearing seats in the lower half of the crank-case, and

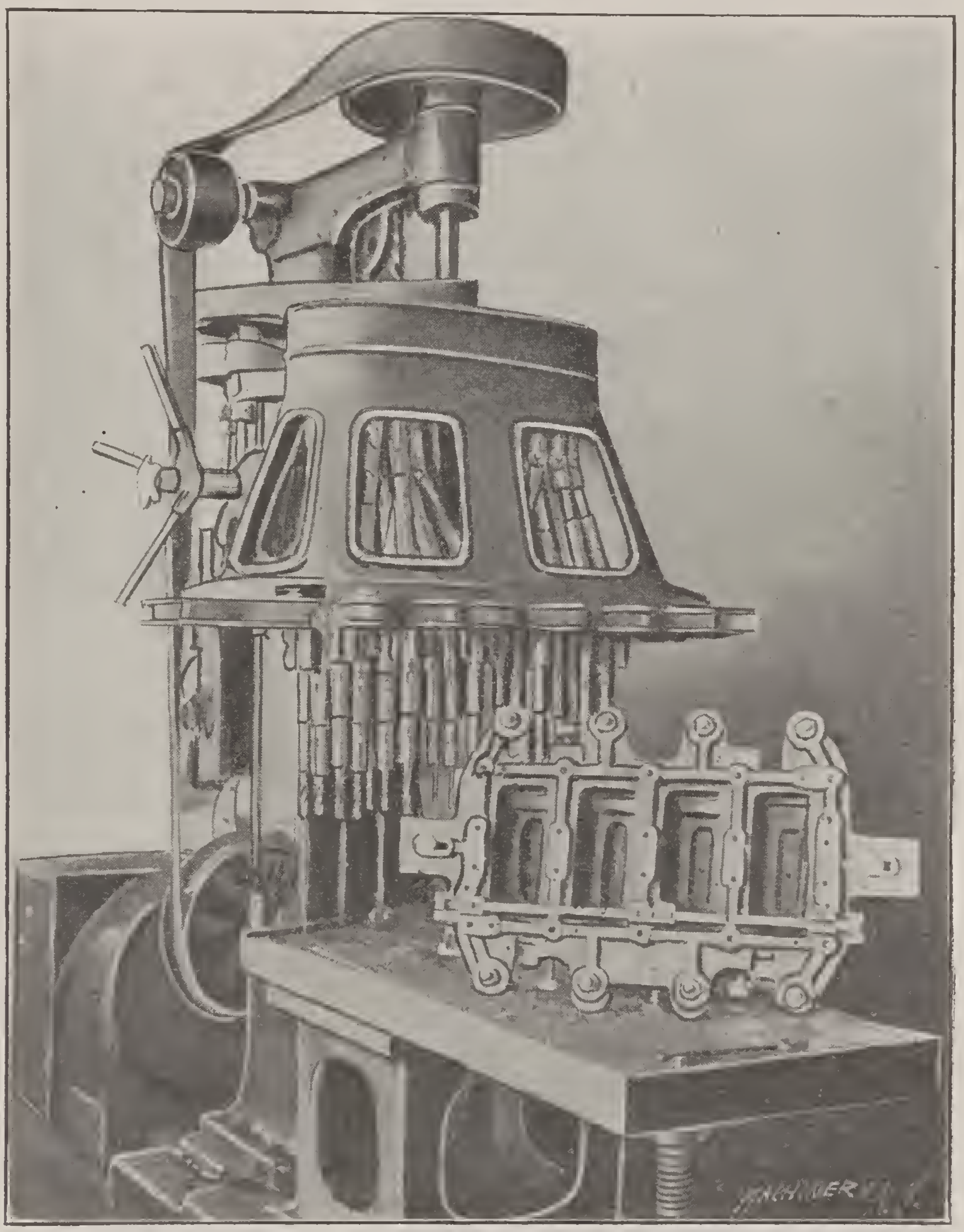

Fig. 22. Twenty-four-spindle Machine for Drilling the Frames

an adjustable hand reamer with a very long pilot is used for finishing them. The variation in size allowed on the bearing bushings is only 0.0015 inch and only 0.001 inch on the shaft bearings.

Cam-shaft

Fig. 24 shows both the cam-shaft drilling and reaming jigs on the same machine table, for convenience. The drill jig (seen in front) is of steel with hardened bushings with an adjustable stop-screw in the end. This jig gives the correct position of the holes for the eight

cams and the drive geams. As the holes are to be reamed in pairs and each pair is 90 degrees from the others, the reaming jig is designed with a view to extreme accuracy. In operation the first hole reamed

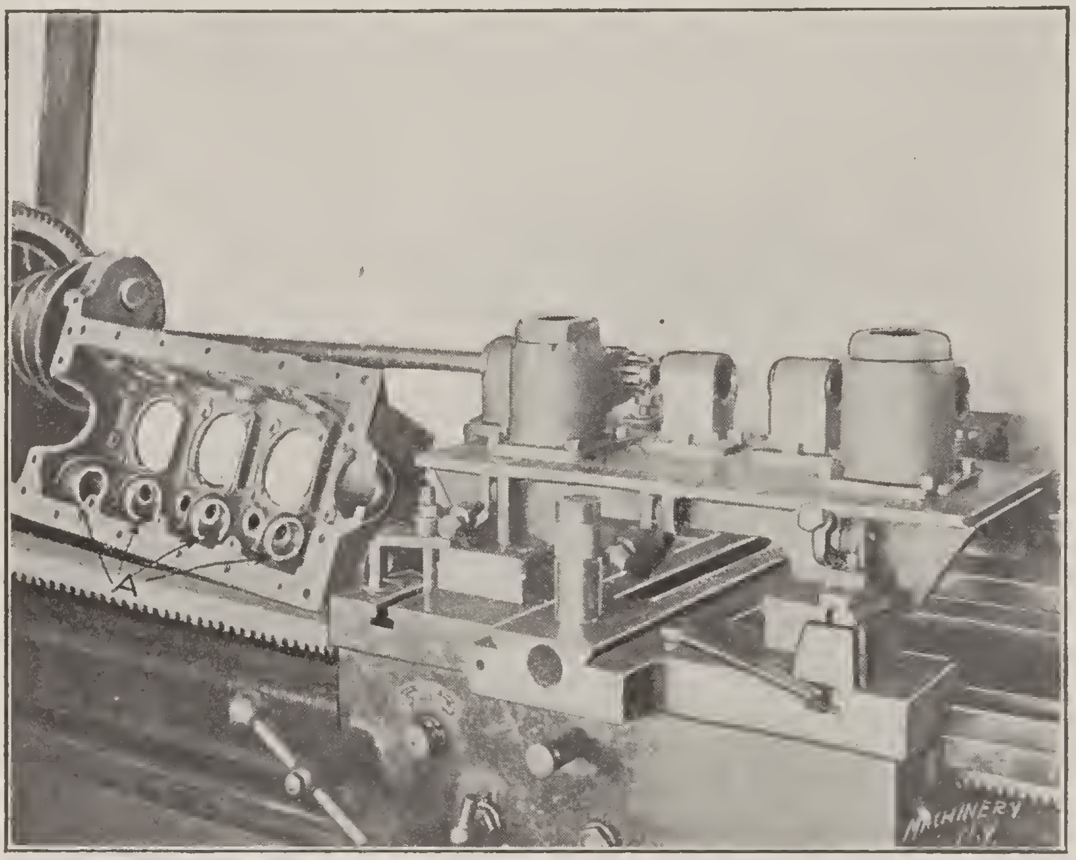

Fig 23. Fixture for Boring Cam-shaft Bearings in Engine Frame

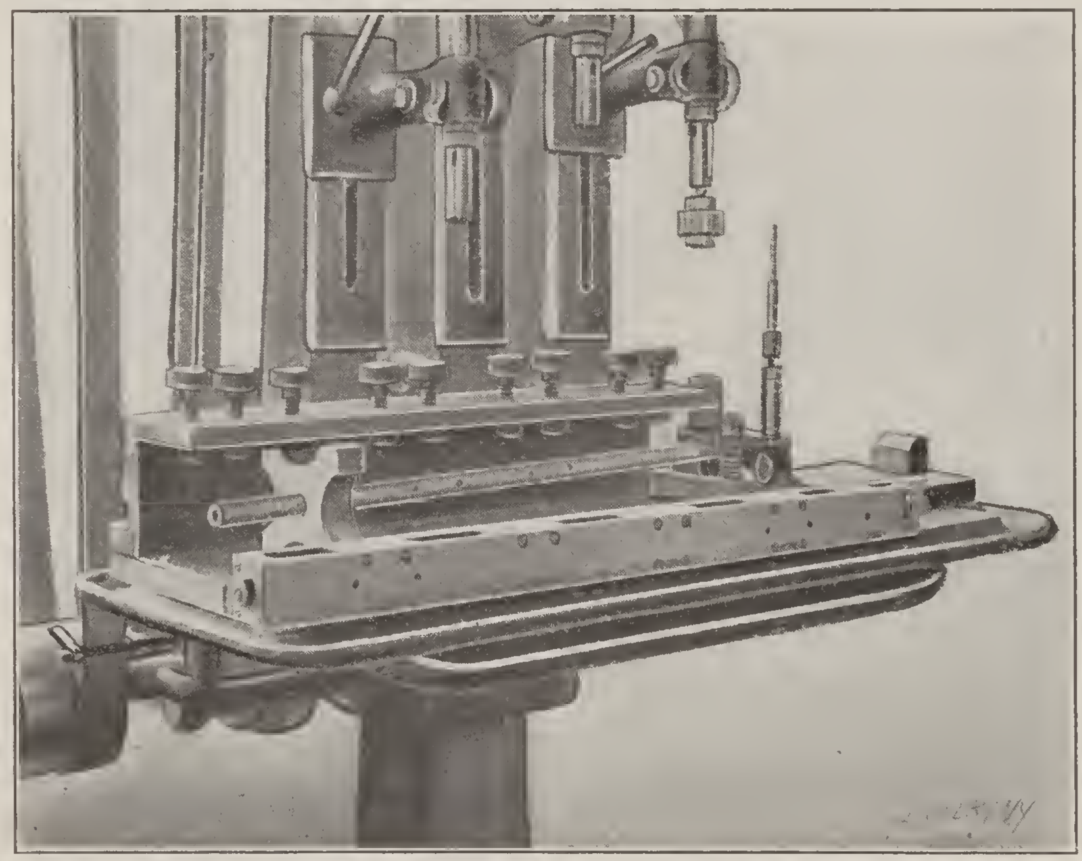

Fig. 24. Fixtures for Drilling and Reaming Cam-shafts

is the one by which the drive gear (Fig. 15, page 18) is pinned on. The taper reamer is guided by the bushing in the clamping fixture at the right, and the collars are so adjusted as to ream the hole to the

required size. The shaft is then slipped through the square, hardened and-ground steel block seen at the left in the illustration, and a master pin is inserted. The block is then slipped along in the frame of the jig and clamped by the screws seen on top of the fixture as the various holes come under the reamer. The projecting block seen at the extreme right end of the jig, forms a rest for the cam-shaft as it is passed along. As the taper holes in the cam shaft, cams and cam-gears, must bear the correct relation to each other, a set of master pins is provided for testing the depth of the reaming. These are hardened and ground tool-steel pins having two fine lines 0.020 inch apart around them at the point where they project through the hole in either the shaft, the cam or the gear. As a variation of 0.001 inch

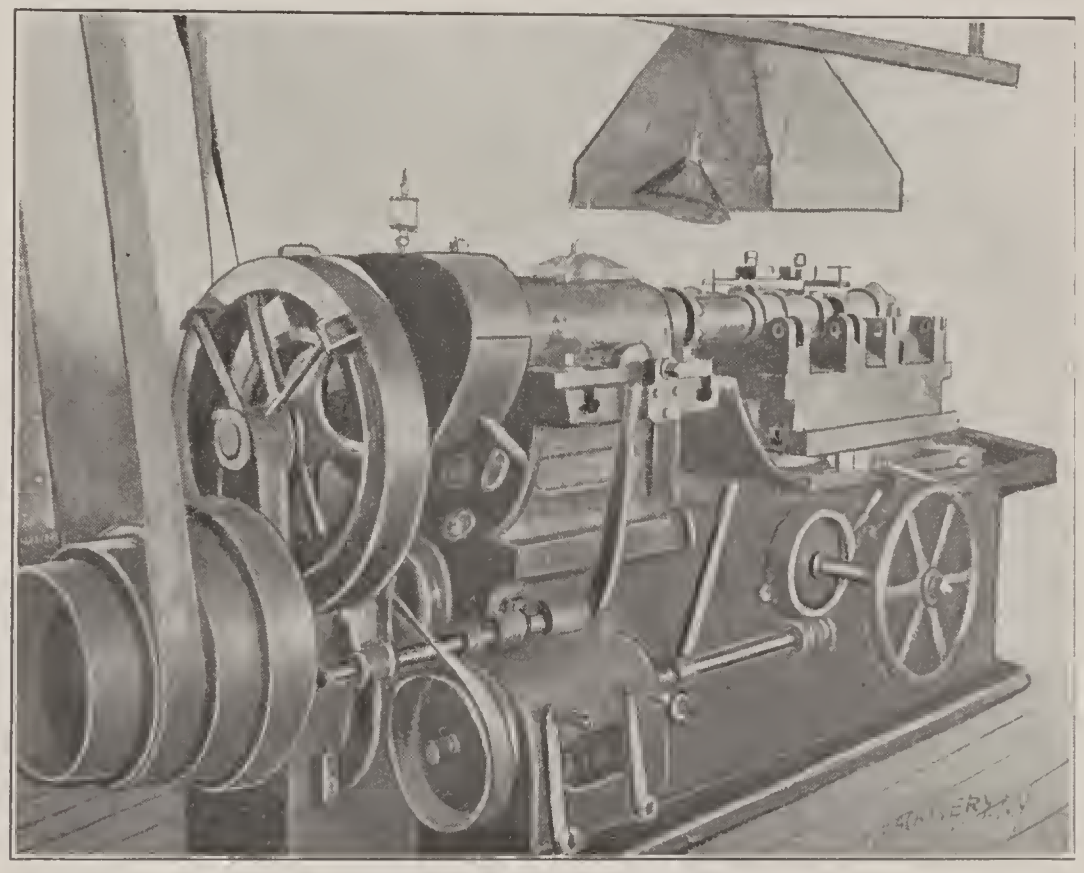

Fig. 25. Boring Cylinders

in the diameter of a standard taper pin hole permits the pin to enter 0.040 inch deeper into the hole, the accuracy of this work can be realized when it is known that no hand reaming is required in assembling the cam-shaft. The cams are drilled and reamed in similar jigs, which, in all cases, locate the cams by the eccentric portions. The inlet cams are alike and interchangeable, as are also the exhaust cams. The cams are of selected steel, hardened and finished by grinding on the working surfaces in correct relation to the pin holes.

Cylinders

Fig. 25 illustrates the method of boring the cylinders in a double spindle Beaman & Smith machine, with a turn-table fixture whereby two cylinders may be changed while two others are being bored. As the cylinder castings are very uniform in size, the boring leaves the walls very uniform in thickness. After being bored and reamed, the cylinders pass to the testing bench where water pressure of 700 to

800 pounds per square inch is applied to test them for leakage. Those passing the test are taken to the screw machine department and put on an expanding arbor in a large Potter & Johnston machine for facing and tapping the top and turning the portion of the cylinder which enters into the crank-case of the motor. The machine and tools for these operations are seen in Fig. 26. The turret tools in the foreground are those used in roughing out and boring the upper end of the cylinder for the cylinder head nipple. The heavy overhanging turret tool finishes the flange on the cylinder for the copper water jacket. The rear cross slide carries the tools for roughing this flange and also the flanges through which the studs pass for fastening the cylinders to the engine frame, while the forward cross-slide tools finish the stud flanges and a portion of the cylinder where it enters the bored seat in the engine frame.

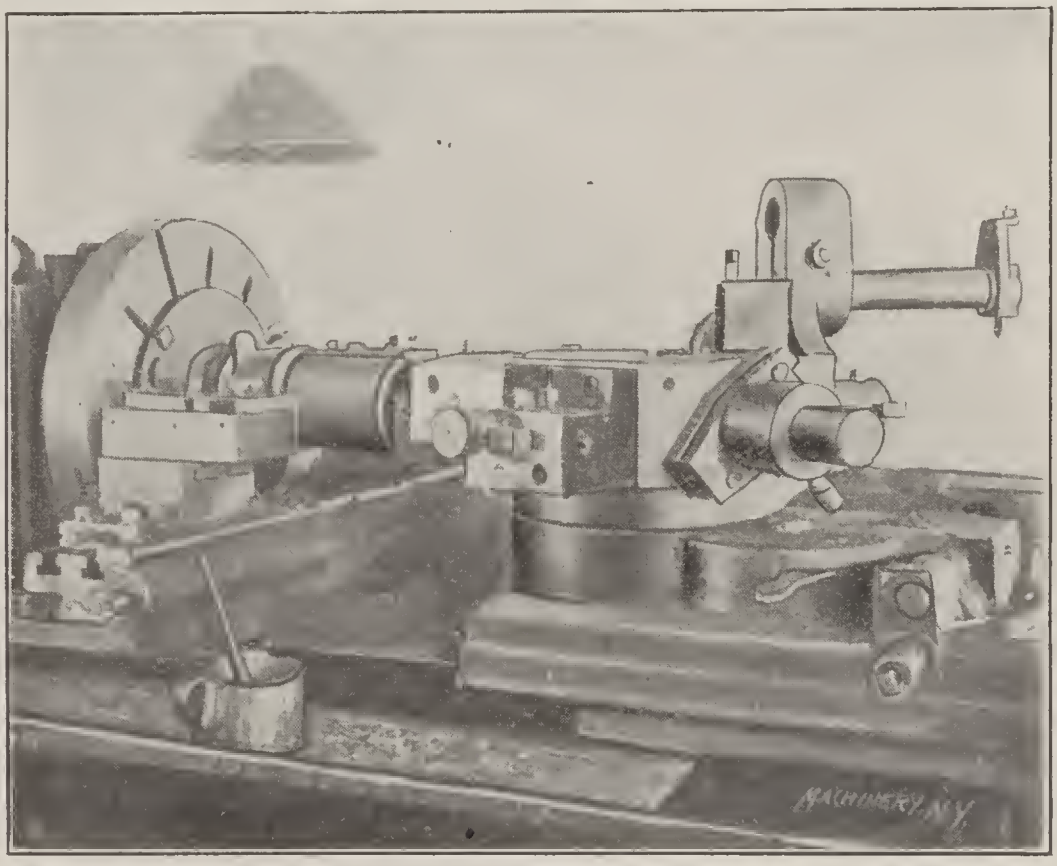

Fig. 26. Turning Cylinders

The cylinders are finished by grinding in Brown & Sharpe and Heald machines. A heavy angle-plate fixture, bored and faced to a very close fit on the cylinder diameter, is fitted to the table of the machine as shown in Fig. 27. The cylinder is clamped to this fixture exactly as it is held later in the assembled motor. Cooling water is supplied to the outside of the cylinder, and the air tube seen at the extreme right conveys the particles of metal and emery to a suction fan at the rear of the machine. The "Go" plug gage seen on the machine table, is 4 inches in diameter and the "Not Go" gage is 4.002 inches in diameter.

Pistons and Rings

The second operation of roughing off the pistons in a Gridley automatic turret lathe is shown in Fig. 28. The first operation is not

shown, as it consists only in chucking and roughing off the outer diameter of the head end for about an inch to permit the steadying roll passing over the end. The upper roll has but a slight travel, as it

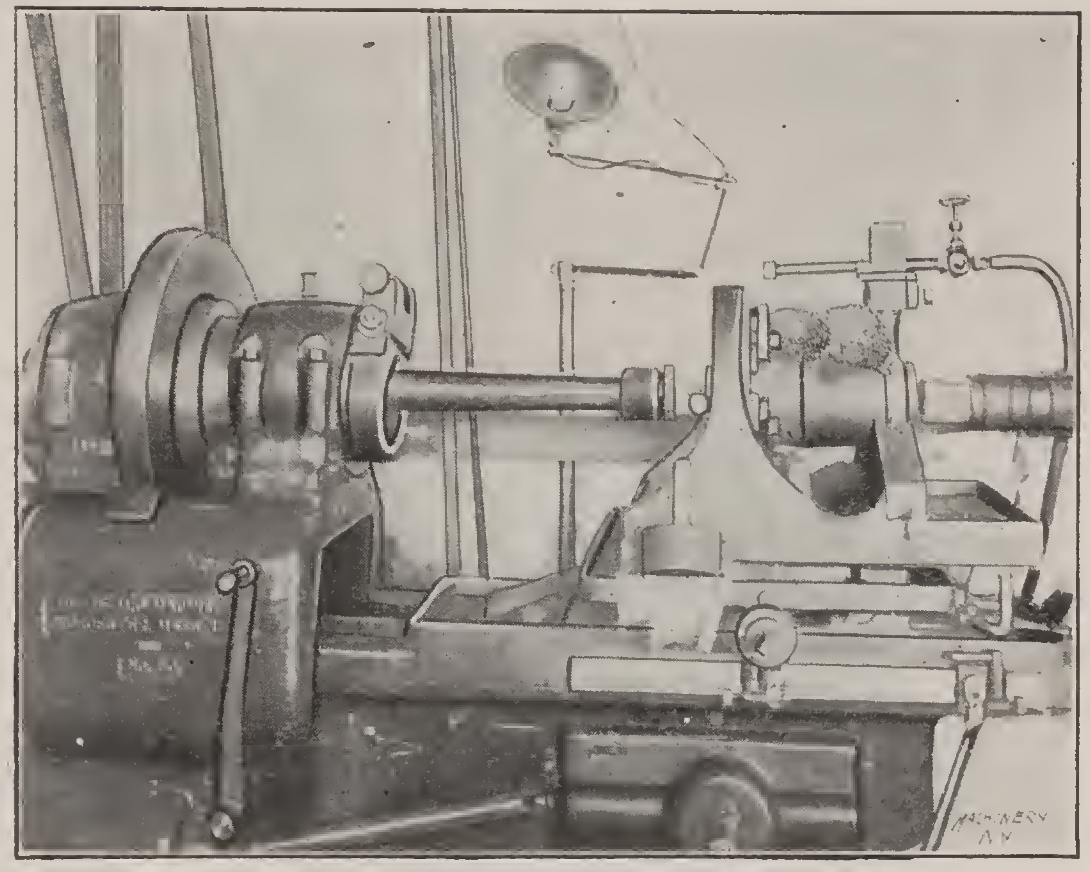

Fig. 27. Grinding Cylinders

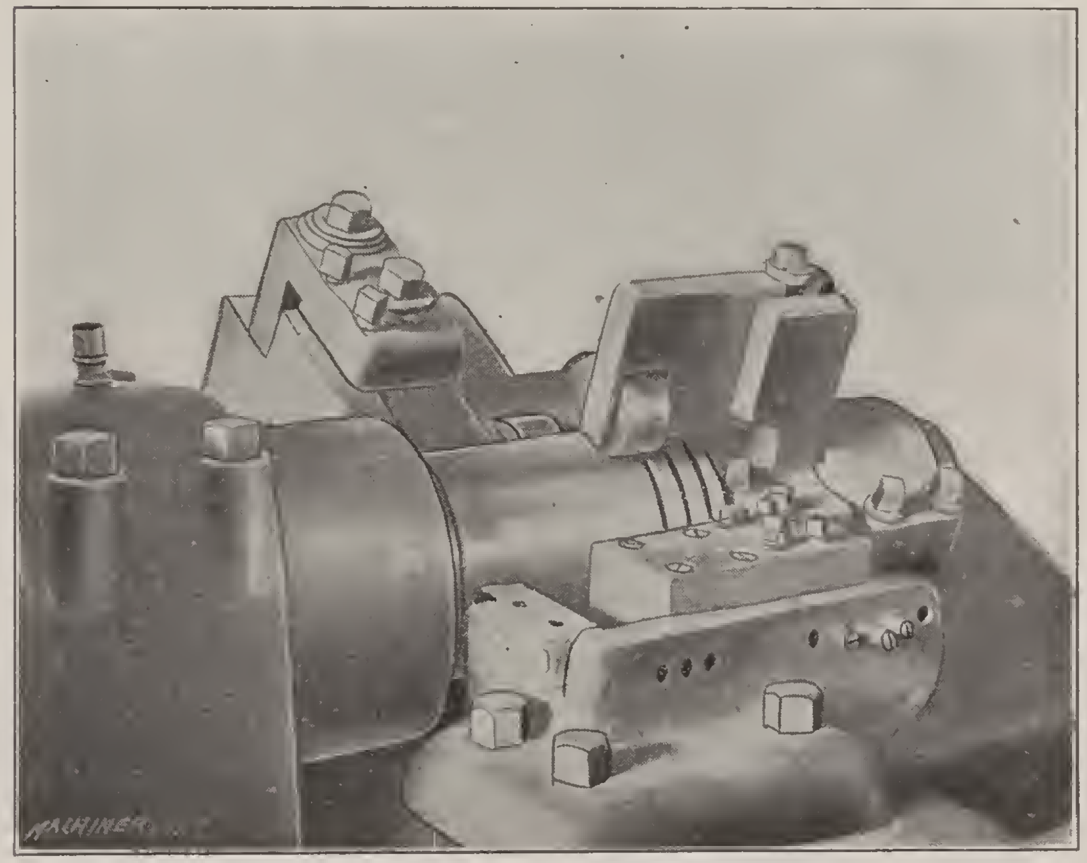

Fig. 28. Turning Pistons

forms a part of the end facing tool. The heavy turning tool is carried in the rear tool holder, which also carries another roller; this roller supports the piston against the side thrust on it, caused in cutting the ring grooves. The view shows the very heavy character of

the tools, and the provisions for adjustment. The piston is held by an internal draw-in fixture, thus permitting the turning tool to travel its entire length. The finish is by grinding in heavy Brown & Sharpe and Norton machines, as illustrated in Fig. 29. The greatest variation in size permitted is 0.002 inch. A finishing cut is taken from the open end of the piston in a special reaming fixture just before grinding, which prevents any possible distortion of the piston due to changes in the metal after the open end has been machined. The piston pin hole is bored in box jigs and 0.001 inch is left for hand reaming previous to assembling the piston and connecting-rod. A final light finishing cut is taken from the piston ring grooves after the piston is ground.

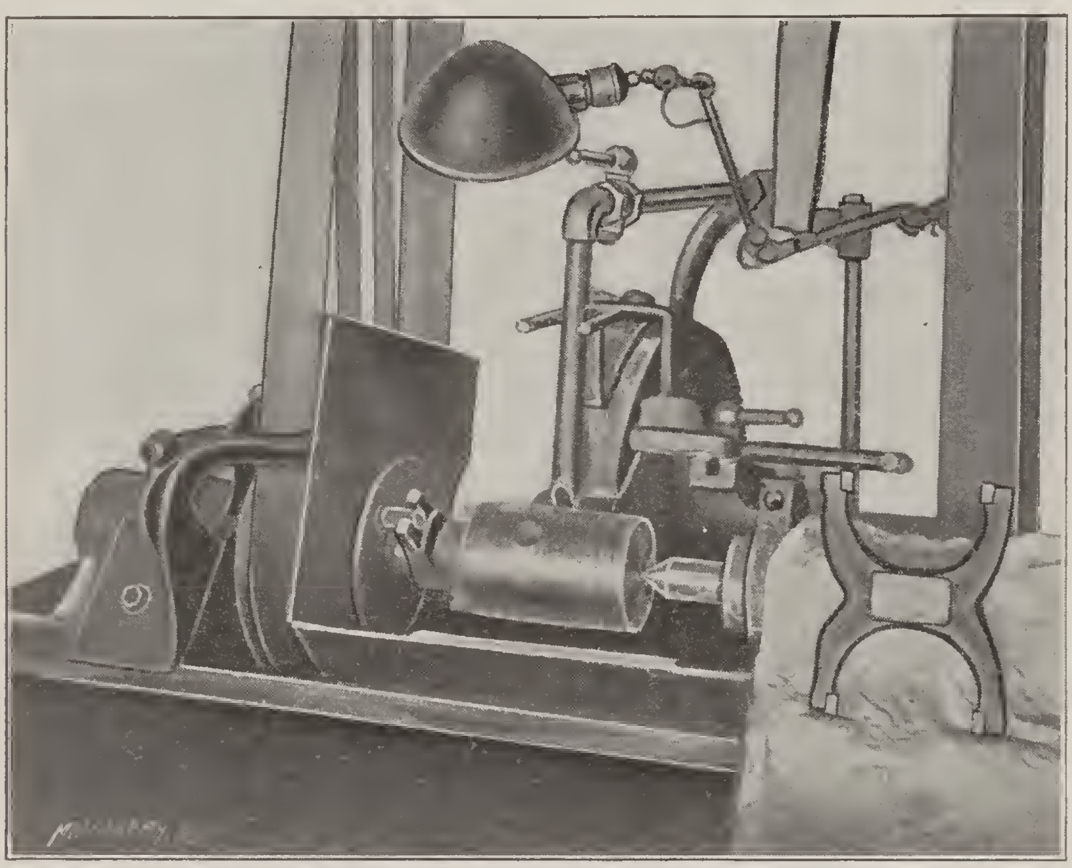

Fig. 29. Grinding Pistons

The piston rings are of a special close-grained iron mixture and are turned and bored on Gridley machines, and finished by grinding. The ring joint is the standard 45-degree angle joint, which has always given good results in practice.

Connecting-rods

The connecting-rods are drop forgings of H-section, having a pressed-in bronze bushing bearing for the piston-pin, and a hinged cap carrying babbitt-lined bronze half-bushing bearings for the crank-pins. While the machining of the rods requires a set of very complete and accurate jigs and tools, limited space prevents their illustration. Two of the fixtures for testing the alignment of the assembled rods, however, are shown in Figs. 30 and 31. Fig. 30 shows the method of locating the piston-pin bushing central with the crank-pin bearing, which is held in the hinged end of the rod by large brass dowels. A plug is placed between the half bearings, and the adjusting screw

tightened down sufficiently to hold them tightly in place. The piston-pin bushing having been pressed in approximately central and hand reamed, is then slipped on the ground arbor which is pressed into the casting and positively held by a large hexagon nut. The knurled nut *A* is then screwed on the outer end of the arbor, thus holding the piston-pin bushing against a ground shoulder on the fixed arbor. The micrometer screw is then brought up until it touches the edge of the crank-pin bearing, a reading taken, and the screw backed away. The nut *A* is then loosened, the connecting-rod slipped off, turned over and replaced on the arbor and another reading of the micrometer screw is taken. The difference in the two readings thus indicates the amount the two bearings are out of line with each other. For

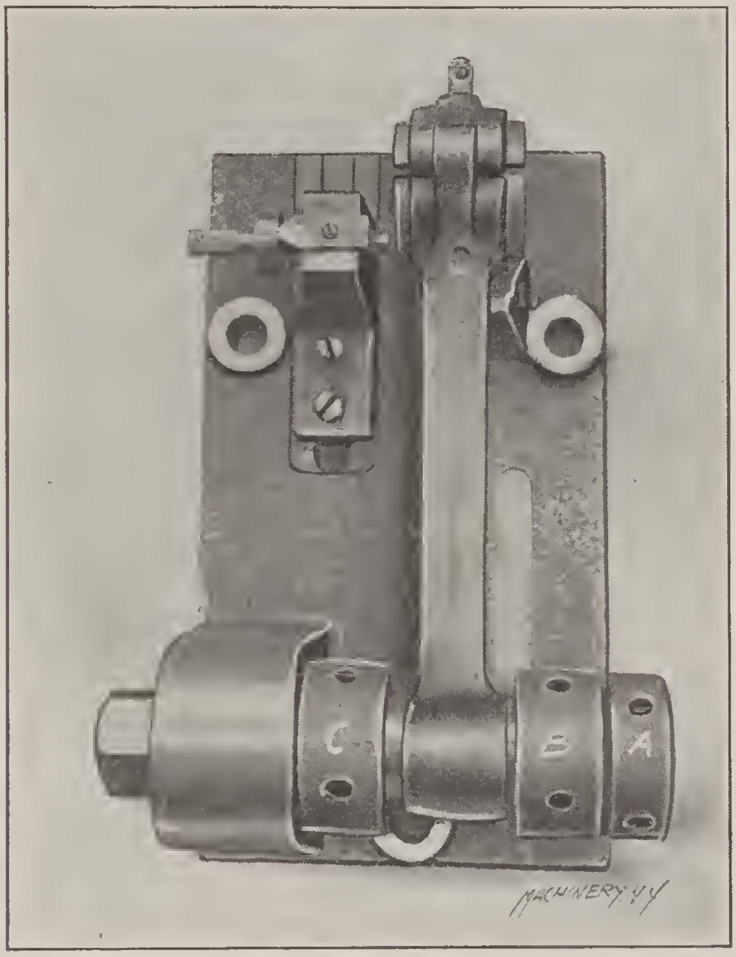

Fig. 30. Fixture for Testing the Relative Lateral Positions of Connecting-rod Bearings

overcoming this variation, the two knurled nuts *B* and *C* are provided. Nut *B* is internally threaded to fit a threaded portion of nut *A*, and in use screws up against the face of the connecting-rod forging for pressing it farther onto the bronze bushing. Nut *C* which is internally threaded to fit a portion of the fixed arbor, operates to move the rod forging in the opposite direction. When the rod is thus centralized, a dowel of brass tubing is put in, which prevents disalignment and also conveys oil to the piston-pin bearing.

For testing the parallelism (both vertical and horizontal) of the rod bearings, the fixture shown in Fig. 31 is provided. In operation, two ground arbors which are tight-fits in the rod bearings, are inserted, and the rod laid in the fixture as shown. A pair of flat springs *A* press the smaller arbor against the inserted hardened and ground

plugs opposite them. A similar pair of plugs are seen at the other end of the fixture; between these and the arbor is inserted the taper strip seen in the foreground. The taper is such that the cross lines which are about 1/8 inch apart each give a reading to 0.001 inch. The two flat strips attached to the lower end of the fixture are so placed for convenience in reading any variation in the position of the taper strip. As all four horizontal surfaces on which the ends of both the

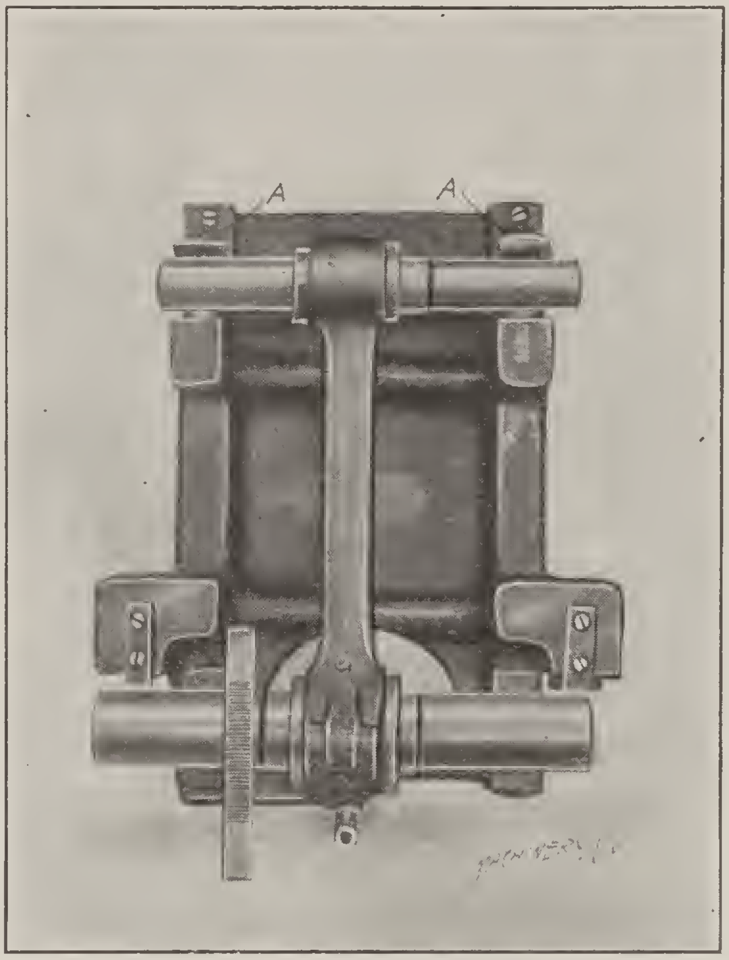

Fig. 31. Fixture for Testing the Parallelism of Connecting-rod Bearings

arbors lie are ground to the same plane, any "wind" in the connecting-rod is seen by the failure of all four points to touch at the same time.

Bevel Gear Templet Milling Machine

A pair of bevel gears are used to drive the short vertical commutator shaft from the cam shaft of the motor, and as the relative positions of the commutator to the cam-shaft and main shaft of the motor must be accurately maintained, the necessity of correctly cut and carefully mounted gears is apparent. For producing these gears, a specially designed machine is employed, which is shown in Fig. 32. The machine is one of the templet type, whose templet or form (seen on the arm at the top of the machine) is primarily developed by rolling contact with a rack. This produces a magnified tooth form which is mathematically correct, and even if it contained any errors these would be reduced in the actual work in the same proportion which the gear tooth bears to the form. Hence, very accurate bevel gears

may be cut on this type of machine, and a brief general description of its main features may be of especial interest.

The machine consists of two principal parts: the work spindle and its driving and indexing mechanism, and the cutters with their driving mechanism. The cutters are driven by round belts, at a high speed, and are mounted on geared spindles which are carried in two vertical slides, which, in operation, have a reciprocating motion on

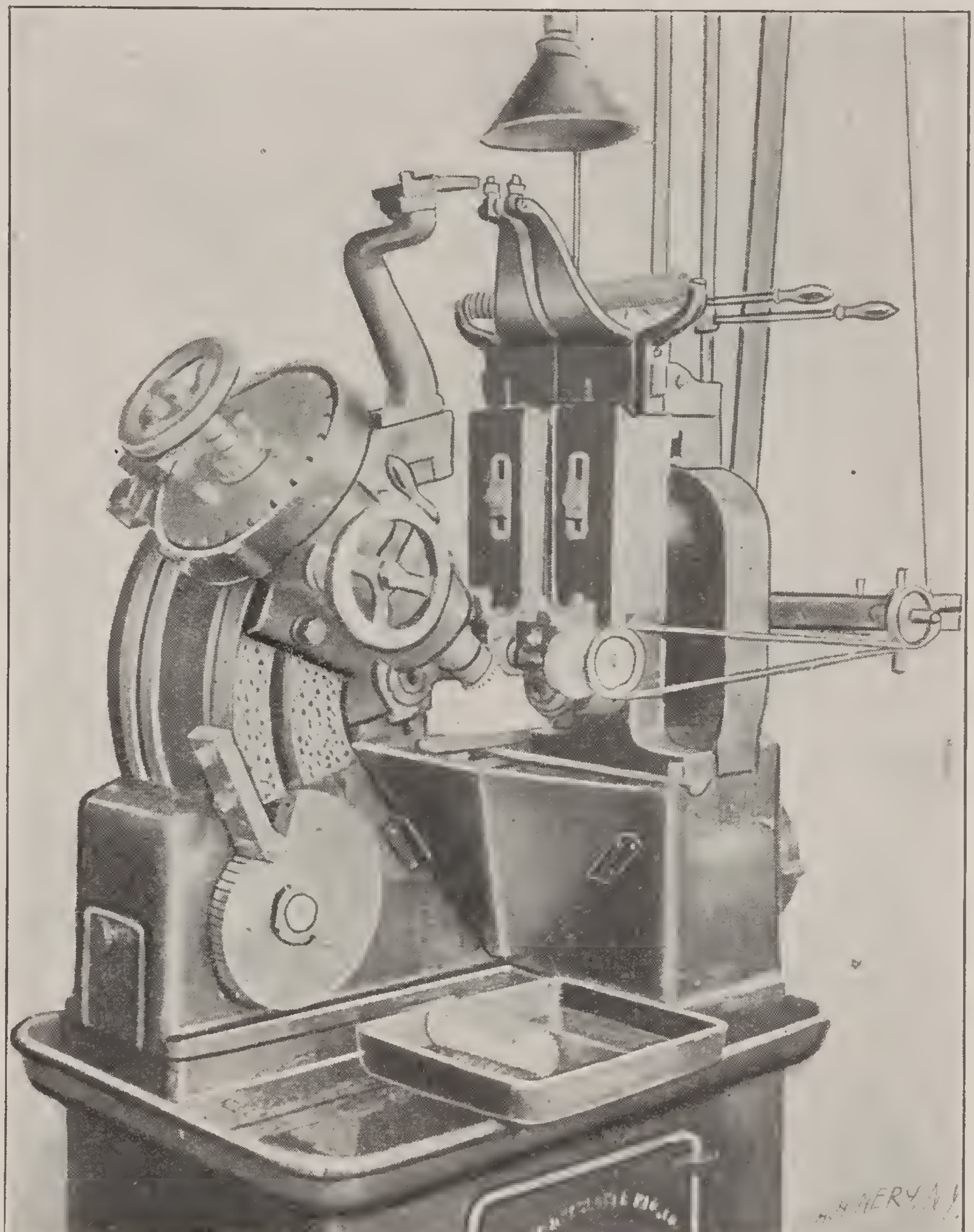

Fig. 32. Bevel-gear Milling Machine of the Templet Type

lines divergent from the cone center of the gear to be cut. The cutting edges of the cutters are thus always traveling along lines which become the clearance lines of the gear tooth. The gear blank is roughed out on a special gashing machine as the templet milling machine is not intended for roughing.

The work spindle is carried in the head, which has a working range of 75 degrees between the horizontal and vertical planes. This head is locked to the movable graduated quadrant, which is pivoted at a point coincident with the center of the gear. The work spindle

has an end movement of several inches, for convenience in changing the gear blank, and has a draw-in arbor attached to the hand-wheel seen above the index plate, for locking the gear blank in position. The index plate is seen at the top of the work spindle. The index trip is set at the desired position on the rear slot of the stationary quadrant. In operation the large cam under the work spindle raises the pivoted quadrant to which the work spindle is locked, and gradually feeds the work forward between the two cutters, which are gradually forced to change their position by the action of the large tooth form entering between the two rolls on the cutter slide arms.

Fig. 33. Fixture for Testing the Accuracy of Commutator Contact Points

The indexing is, of course, automatic, and occurs at the position of the cam shown in the engraving. This cam has, as shown, an edge consisting of a series of small steps, rather than a gradual curve, and is so geared to the cutter spindle mechanism that the work is fed into the cutters at the ends of the stroke of the cutter slides, rather than during a cut. The index mechanism shows careful thought in its design, in that the index pin enters the slots in the index plate in such a manner as to have no sliding contact on the master edge of the slot. An automatic trip stops the machine when the gear is finished. This machine is one of a series which was built by this company (then the Leland & Faulconer Manufacturing Company) in 1898-1899, for producing either soft or hardened and ground bevel gears, the machine being designed to produce finished soft gears, or semi-finished gears for hardening.

Commutator Testing

Fig. 33 shows a fixture employed for testing the accuracy of the spacing of the contact points of the commutator. This fixture consists of a central portion carrying the commutator shaft, and of an outer graduated steel disk movable on the central part of the fixture. In operation, a commutator is slipped on over the stationary shaft and the bearings adjusted. The commutator brush is then placed on the shaft and locked in place, leaving the commutator body free to be revolved. A battery and coil which are a part of the fixture, indicate the electrical contact by the buzzing of the coil. The pointer is then put in place and clamped, and the commutator turned until a contact is indicated. The large outer disk (about 18 inches in diameter) is then turned around under the pointer until one of the 90 degree graduations are directly under the pointer. The commutator and pointer are then turned to bring the other contacts to the brush, and their variation read on the large disk, which is graduated in degrees at four equi-distant points around its edge. The requirement is that the commutator contacts be spaced 90 degrees apart, and the variation allowed is only one-half a degree, as the relation of the firing to the piston and valve movements must be very exact.

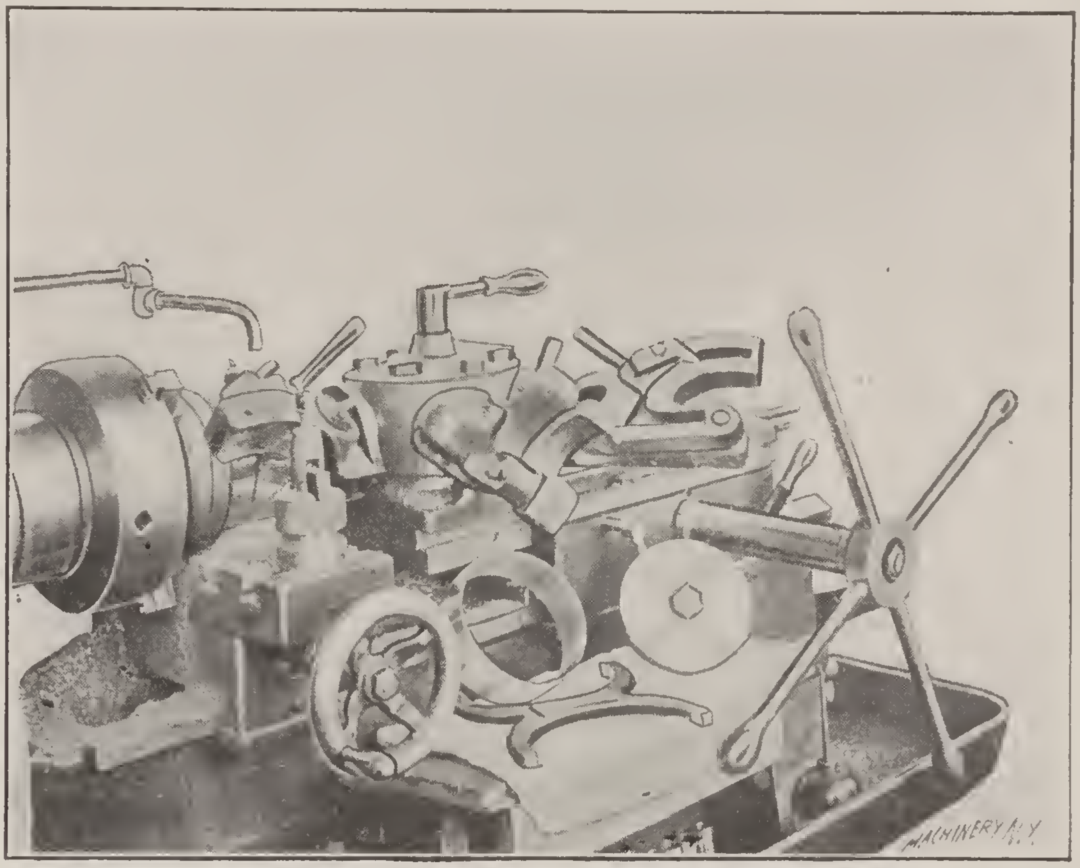

Fig. 34. Turning a Spherical Ring

Fig. 34 illustrates a nice piece of screw machine work in the brass shop. The ring seen leaning against the machine is of bronze. The diameters of these rings range from 6.497 inches to 6.500 inches and the bore from 5.878 inches to 5.880 inches. The outside is spherical in shape, and the ring forms a part of the rear universal joint housing which swivels on the rear axle driving shaft casing, and also slides

in to compensate for the rear spring action. Slight variations in size and a fine finish are necessary to make this point oil tight. A casting is seen in the machine, and a roughing cut is being taken from the outside. It has already been rough bored, enough metal being left for a fine finishing cut to be taken after the outside is finished. The castings have heavy flanges for inside chucking, so that little trouble is experienced by their springing after being parted. The illustration shows the construction of the spherical turning tools, and two of the gages used.

CHAPTER III

SYSTEM FOR THE RAPID ASSEMBLY OF MOTOR CARS*

From a mere corner in the machine shop in the days when the automobile was built in lots of but two or three at a time, the assembling room has grown to such an extent that, in many factories where the output is large, it occupies an entire floor of the main building, and has come to be considered as one of the three or four most important departments of a modern motor car factory. A corresponding increase in responsibility has attended the growth in size and importance of the assembling room, and to-day, unless well managed and equipped with the most up-to-date devices for the convenient and rapid handling of parts, it can easily "eat up" the profits on a whole year's output of low or medium-priced cars. Without requiring the services of an excessive number of men, it must take care of the parts from the machine shop and the parts-assembling room as they are turned out, and not allow a great number of finished pieces to accumulate at any time in the stock room. The work of assembling must also be done thoroughly, so that, when tested, the complete car need not be sent back for overhauling and readjustment of parts. In short, the assembling room must work in harmony with each of the other departments in doing its share toward producing a car of maximum quality at minimum cost of production—and that share is by no means small. But not alone are the best systems and business management, proper interior arrangement and most up-to-date devices necessary, but the highest class of skilled mechanics must be employed as well. A motor and transmission may be composed of the best of materials and have bestowed upon them the most skilled workmanship available, but unless they are placed together in the completed car with each shaft lined up, each bearing scraped and fitted and each gear in position to mesh properly, all this expensive material and labor may count for naught. The assembling room cannot, to any great extent, compensate for poor machining, but it *can* absolutely ruin the best products of the machine shop.

That the leading automobile manufacturers have been brought to a realization of the importance of the use of the best systems, equipment and labor in their assembling rooms is particularly well exemplified in the factory of the Chalmers-Detroit Motor Car Company at Detroit, Mich. Probably the most convincing proof of this statement will be found in the fact that, for the 3,000 complete cars turned out by this company last year, not more than 30 men were employed at any one time on the assembling room floor. More remarkable than

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* MACHINERY, October, 1909.

this, however, is the high record established for a day's work. In ten hours, the 30 men in this department assembled 35 complete cars! Of course this does not include the assembling of the small parts of the motor, transmission and rear axle, as these are taken care of in other departments, but when it is remembered that the chassis assembly *does* include the installation of all these parts in the frame, the adjustment of each to its new position, the attaching of all springs, wheels, running-boards, foot-rests, steering gear, and the wiring and piping of the motor, it will be realized that the system and equipment employed in this department must be perfect in every respect, in order to turn out this amount of completed work.

The headquarters of the assembling department may be said to lie in the finished stock room, which occupies a large section of the floor of the main factory on which the assembling room proper is located. To this finished stock room come all finished parts such as nuts, bolts, screws, front axles, springs, and wheels, and the previously assembled motors, transmissions, steering gears, and rear axles. These are all classified and placed by themselves, the smaller parts being kept in bins which extend in long rows down one end of the room. Lists pasted in conspicuous places along these bins show the exact number of each size and kind of bolts, nuts and other pieces required for the various models of cars made here, and hand trucks having bodies divided into compartments are drawn down past the bins and filled with the necessary number of small parts for two cars. In the larger divisions of the truck box or body are placed the axles, steering gear, running boards, foot rests, and other bulky parts of the car. Each truck is filled with a sufficient number of the proper parts for the complete assembly of two cars and is then rolled into the assembling room, adjoining the stock room, and placed between two pressed steel frames which form the foundations, as it were, of the two chassis to be assembled. Having received the required number of parts of the proper kind, three men now devote their entire time to assembling the two chassis—and it is here that the advantages of "team work" are exhibited. Having become accustomed to this method of assembling, each man knows just what he is to do, and always has the other chassis at hand to which he can turn his attention when he is liable to interfere with the work of his two companions. It is highly specialized work, each team of three men devoting their whole time and energy to the installation and adjustment of the various parts of two cars until they are ready for the road test. As the three men finish the first two chassis, another truck is brought in containing parts for two additional cars, and the team then devotes its attention to cars three and four. The motors are not included in the quota of parts comprising the truck load, but are carried in separately by differential hoists which travel on overhead tracks and pass in two lines down the sides of the assembling room in front of the two rows of chassis. When the frame is ready for the installation of its motor, the latter is lowered in place. This system renders each car independent of the stock room after the truck load of parts has been received,

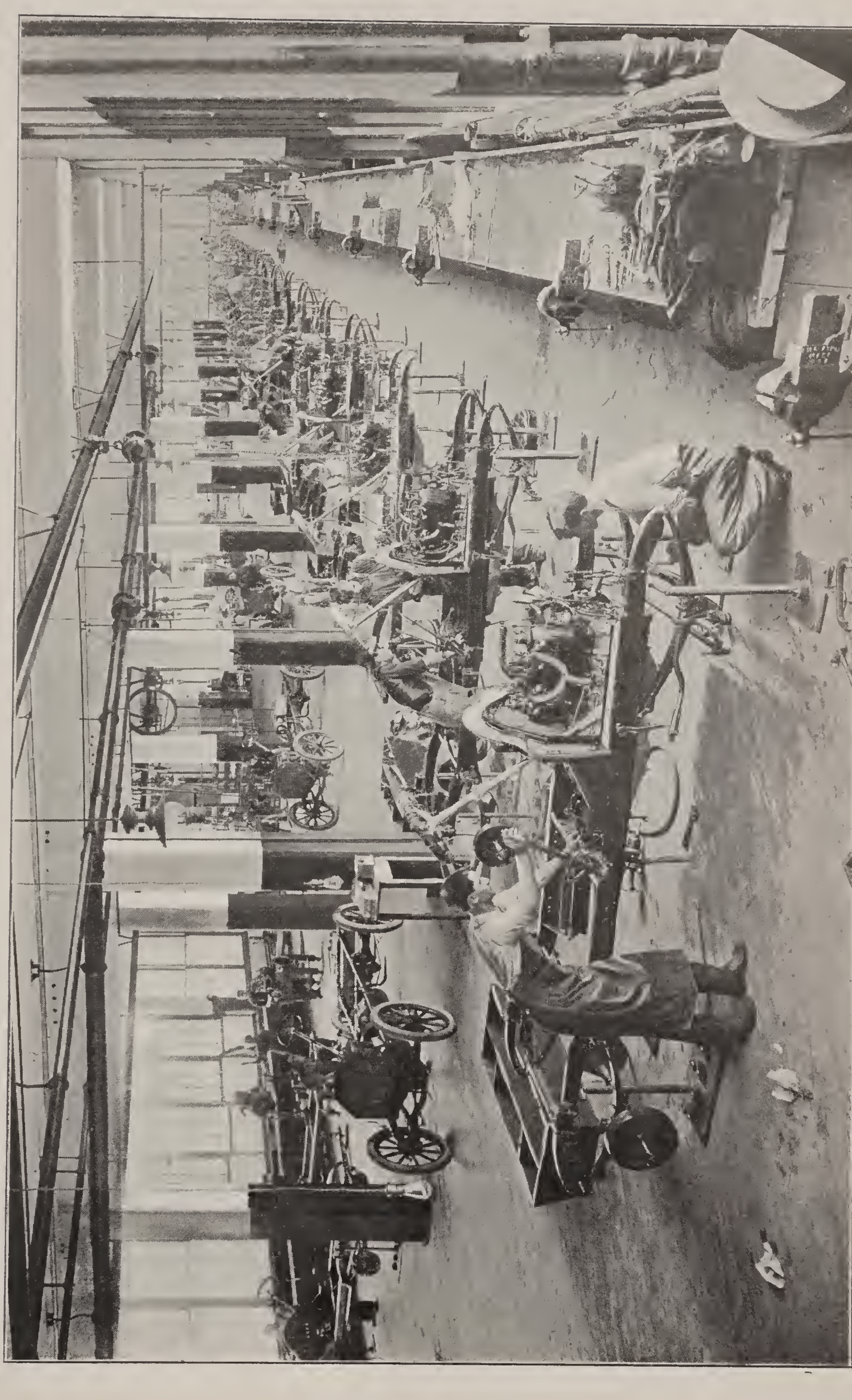

Fig. 35. View of the Assembling Room, showing Arrangement of Overhead Track and Differential Hoists, the Trucks, each of which holds the Parts for Two Cars, and the Adjustable Frame Supports

and the work bench, vise and kit of tools near every chassis reduce to a minimum the number of steps necessary to be taken by each workman.

The arrangement of the rests for holding the frames rigidly in place is very ingenious and entirely does away with the use of saw-horses or other movable and bulky supports. There are four of these supports for each frame, as shown in Fig. 35, and when not in use, one or all may be let down into the floor. Each of these supports consists merely of a vertical iron rod, bent at right angles at its upper end and forged into the shape of a hook. A corner of the frame rests on this horizontal portion of the rod, while the hooked-shaped ends of the two opposite supports prevent lateral motion in either direc-

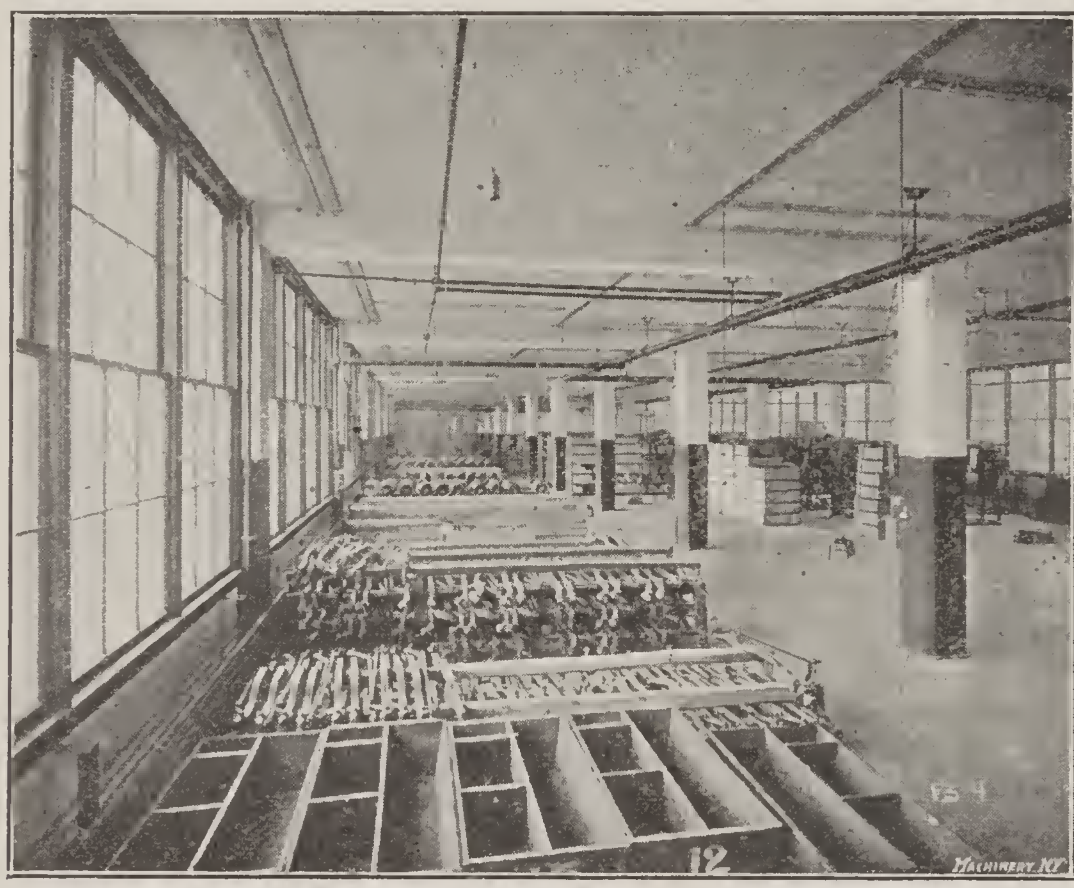

Fig. 36. View of Stock Room, showing Trucks in which Parts are taken to the Assembling Room

tion. Each rod is supported by a pin passing through it at the proper distance from the end, which rests across the top of the base-plate which is bolted to the floor and through which the end of the rod passes. By giving a partial turn to the rod, the pin is allowed to pass through a slot in the base-plate, and the whole support is thus dropped until its top is flush with the floor. In order that the supports may accommodate themselves to various lengths of frames, the rear pair of every set of four base-plates is made with four sets of holes, in any of which the rods may be placed. The sets of supports are placed at such intervals along the floor that sufficient space between the frames is allowed to enable two teams of men to work on adjoining cars without interference. While it may seem a small matter, the facility with which these supports may be put in place, adjusted or removed from the floor helps to make possible, in no uncertain degree, the record for the rapid assembly of cars of which this factory can boast.

Although not a part of the assembling room proper, the department in which the pressed-steel frames of channel-section are prepared for the chassis, has an important part in facilitating quick assembling. When the frames arrive at the factory, forty or fifty holes must be drilled for the various parts which are to be attached, such as the gear shift, brake levers and their supports, the motor, transmission, running boards, fenders, lamp brackets, springs, and the like. Most of these, with the exception of the motor and transmission, are riveted in place before the frames reach the assembling room. These operations are performed in the frame riveting room, which contains several unique and ingenious arrangements that, so far as efficiency is concerned, bring this department on a par with the assembling

Fig. 37. Room in which the Frames are drilled and riveted by Pneumatic Tools

room. The frame is first placed on a set of supports similar to those used in the assembling room, except that a tension rod and turnbuckle connect both pair of rods for the purpose of holding the frame more rigidly in place. A single track over this set of supports carries a differential hoist, from which is suspended a large jig (see Fig. 37) containing a guide hole corresponding to every hole necessary to be drilled in the sub-frame, which carries the motor and transmission. This jig is clamped securely in place and the holes drilled by means of pneumatic drills connected to flexible piping. When all the holes are drilled in this manner, the frame is removed to another set of supports a few feet distant, where it is held rigidly in place in the same manner as that before described. Above this second set of supports is an oval track of the same length and width as the frame. From the traveler on this track is suspended a cable terminating in a single pulley through which passes a chain. On one end of this

chain is a heavy, penumatic riveter, which is counterbalanced by an iron weight attached to the other end of the chain. This enables the tool to be placed at any height desired without unnecessary exertion. A small forge (not shown in the illustration) in one corner of this room heats the rivets before they are driven into the frame. By means of the oval track and pulley, any vertical or horizontal plane bounded by the frame may be reached with the riveter, and four or five men in this department are usually able to keep the assembling room supplied with the required number of frames. After being finished in this department, however, the frames in all cases are taken directly to the finished stock room, from which they are drawn out to the assembling room as needed. This stock room, in facts, acts as a sort of clearing house for the whole factory, and no part ever reaches the complete car until it has been inspected, checked and entered in the stock room records.

The keynote of this system is specialization. Every man knows what he has to do—and he does it. There is no overlapping of departments. It is scarcely ever necessary for the men in the assembling room to step into the stock room, and the men in the stock room are supposed to keep the men in the assembling department supplied with the necessary parts for the cars that have been ordered to be finished that day. Each team in the assembling room follows its two cars through until they are ready for the road test, and it is then easy to place the responsibility for any defect where it belongs. When this system is supplemented with such labor and space saving devices as are used in the assembling and frame riveting rooms, and when, at the head of it all is able, efficient and experienced management, one can begin to understand the conditions which allow the immense increase in production and the reduction in cost of the American-made motor car of to-day.

CHAPTER IV

TREATMENT OF GEARS FOR AUTOMOBILES*

There is probably no part of an automobile that is subjected to more use or greater abuse than the transmission. Carrying as it does practically all of the power developed by the motor, and, receiving at the hands of a careless driver the strains imparted by a suddenly

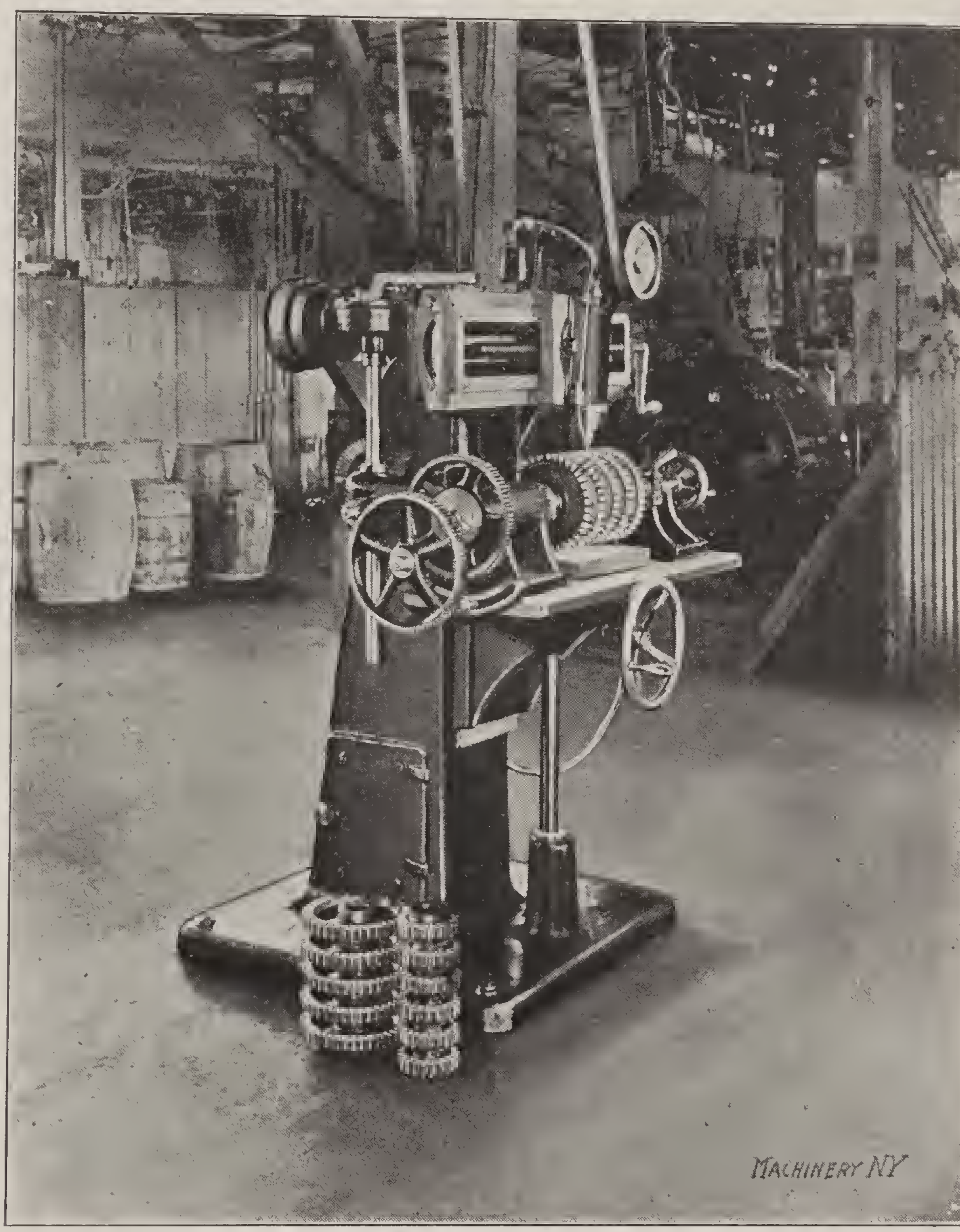

Fig. 38. Chamfering the Teeth of Spur Gears in the Winton Factory

applied load or a too rapid shifting of the speeds, it is small wonder that the gears of the transmission must be made of the highest grade of materials, and that the care and workmanship bestowed upon each must be of the best. The ordinary automobile transmission consists of a series of different sizes of spur gears mounted on two parallel

* MACHINERY, October, 1909.

shafts with means for sliding the gears on one shaft into mesh with those on the other, as desired. In this manner various speed ratios are transmitted from the motor to the main driving shaft, although on the majority of automobiles the high speed drives the car direct, without the interposition of any of the gears of the transmission.

As a saving in weight is an important factor to be considered in the design of a transmission, the gears must be made as small as possible and yet be sufficiently strong to carry suddenly-applied loads with no attendant danger of breaking. Owing to the methods by which the speeds are changed, and the clashing and "bruising" which take place when the gears are shifted, the transmission must also be made of a material which is hard as well as tough. Different kinds of steel have been used and each has been treated by various methods in an effort to discover the perfect gear material, but although this

Fig. 39. Gear Case-hardening Room in the Premier Factory

is yet to be found, the transmission of a modern, well-made automobile, when intelligently handled, will last nearly as long as the car itself. Of the various kinds of carbon steel which have been employed for transmission gears, nickel, chrome-nickel and silico-manganese seem to have more adherents among the leading builders than any other materials. In most factories the gears are case-hardened after being cut, and in this manner the combination of toughness with the desired hard surface is obtained. Gears which have been treated in this way have been taken out of cars after having been run many thousands of miles, and in some instances, the original tool marks on the faces of the teeth were still visible.

Methods employed for cutting gears in automobile factories do not differ in any essential features from those used in any well-equipped machine shop or manufacturing concern. Most of the automobile makers purchase their transmission gear blanks outside and cut and finish them in the factory. Many of these blanks of special steel are

imported from France, but a few of the leading factories have laboratories of their own in which experiments on high-quality materials for transmission purposes are continually in progress. Six or seven spur gear blanks of the same size are generally placed on the mandrel of the cutter at once. A continous cut extending throughout the width of all these blanks is then taken for each tooth, and in this manner six or seven gears are finished at once and are made absolutely uniform.

After the teeth have been cut, the gears are taken to the heat treating room to be case-hardened. In the Middle West, and a few other sections, many of the case-hardening ovens are heated by natural gas obtained from near-by wells. In the Maxwell factory, at Newcastle, Indiana, a special machine has been installed for the manufacture of gas from "distillate"—a hydro-carbon obtained from the oil refineries. This machine is set up in the power house connected with the factory, and the gas is stored in a tank located in the same building. It is conducted from here to the heat-treating ovens in which it is used for case-hardening, tempering and annealing. Still another method for obtaining heat for the ovens is in use at the Ford factory, in Detroit. Petroleum, or crude oil, is vaporized and forced by air pressure into a series of special burners located under the ovens. By regulating the amount of air or vapor or both, the ovens can be kept at a uniform temperature, or the amount of heat generated may be varied at will between almost any limits. The temperatures of the ovens are indicated by an electric pyrometer connected with each, and pieces to be case-hardened are kept at a heat of 1,600 degrees F. for a length of time which depends on the depth below the surface to which it is desired to carry the treatment.

In several factories the final operation bestowed upon the gear, before assembly in the transmission or the motor, is the sand blast which serves to scour off any roughness or stains which may have been left on the surface during the cutting or the heat treatment. In the National factory, at Indianapolis, this operation is conducted in a small building separated from the remainder of the shop. The sand is kept in a bin in one corner and is sucked up by a centrifugal blower and forced by the air pressure through a pipe which terminates in a nozzle. The sand, being forced out at high velocity by the air pressure, may be directed at all parts of the pieces to be cleaned. This is one of the most efficient methods of polishing and finishing a gear and does not injure the hard metal surface in any way.

As silence of operation of all moving parts is one of the principal requisites for a motor car of to-day, it is necessary that the teeth of all gears shall be made to mesh perfectly and smoothly with all of those on the other gears with which they come in contact. In order to obtain silence of operation, the gears are run with each other for some time and each tooth is worn to a more perfect fit. The first few weeks of operation by the customer would wear the gears in properly, but, in order to produce a perfect car, this is done before it leaves

the factory. Most of this "running in" of the gears can be accomplished by the thorough road test to which the whole car is subjected before leaving the shop, but many of the leading factories supplement this with additional methods for obtaining the required wear on the transmission. A special frame is used in the Marmon factory, in Indianapolis (see Fig. 40), in which the transmission, driving shaft, differential, and rear axle and wheels are set up. An idler and a driving pulley, with a belt shifter, are attached to the front end of the transmission shaft and connected by belt to a countershaft driven from the main line shafting. When the power is applied and the different speeds of the transmission are thrown into mesh by the shifting lever, every gear of the whole car, with the exception of those

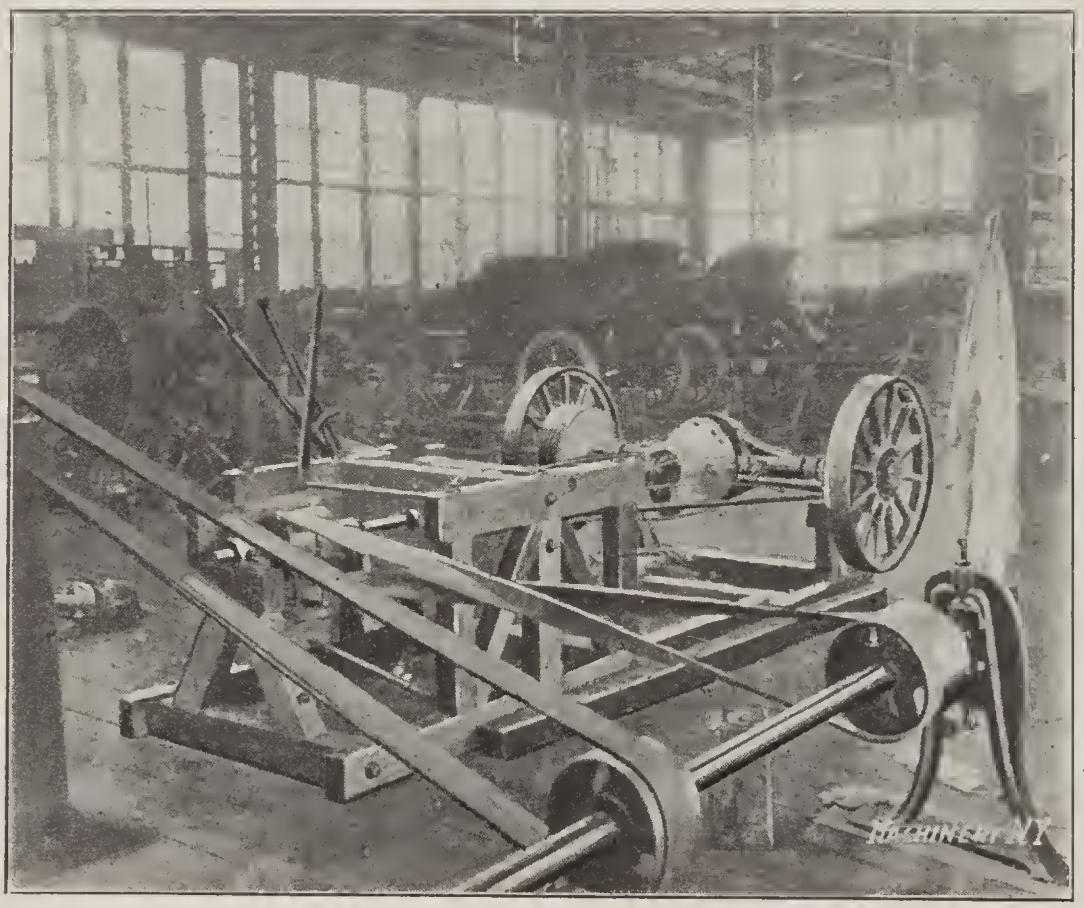

Fig. 40. Running in the Transmission and Differential Gears in the Marmon Factory

used on the motor, will be set in motion. The gears of the engine are worn in when it is operated under belt power before installation in the chassis. Somewhat the same method is pursued in the Packard factory, in Detroit, the only difference between the two being that here, instead of allowing the wheels to run free, a brake is attached to the end of the driving shaft by means of which a variable load may be applied to the gears in mesh. A section of the testing room is devoted to this purpose, and as the transmission and rear axle are assembled, they are brought in, placed on special frames provided for the purpose and connected by belts to the overhead shafting. As the gears of the transmission and differential are run in, the loads are increased until all are worn perfectly smooth.

Before their final installation in the motor and transmission, all of the spur gears for the Winton cars, made in Cleveland, are set up

in a special case and run in under belt power. The bearings in these special cases are set at the proper distances apart to accommodate the various gears of a train, thus wearing in the gears so that all of those for similar parts are absolutely interchangeable. The case is made oil tight and a mixture of finely powdered emery and lubricating oil is fed through an opening in the top so that this grinding material will come in contact with all the teeth of the gears in mesh in the train. This grinding is continued until each tooth has been worn perfectly smooth and to an accurate fit with the teeth of the other gears with which it comes in mesh. For the gears used in the front of the motor to drive the cam, pump and magneto shafts—gears which always occupy the same relative position in regard to each other—a tooth of each is marked when in the grinding case with the corresponding teeth of the others with which it meshes. This is done so

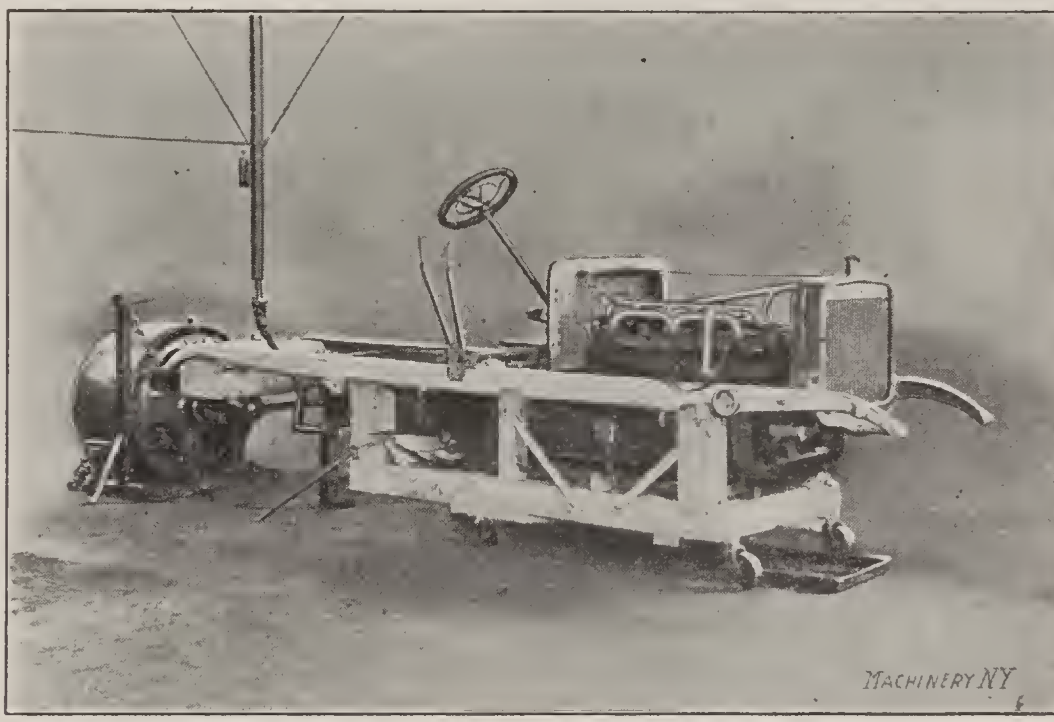

Fig. 41. Preliminary Run of Engine and Transmission to wear in the Parts

that each gear of the train may set up in the motor in the same corresponding position as that occupied while being worn to a perfect fit with the others in the case. It is evident that every tooth cannot be of *exactly* the same size and shape, and if each tooth is allowed to mesh with those with which it came in contact while being ground, more perfect rolling contact will take place and less friction and noise will result. The marks made on the gears are also useful for timing the magneto and valve cam shafts when an occasion arises necessitating the removal of any of these parts from the motor. Of course, it is impossible to carry this practice to the transmission, for most of the gears on one shaft revolve independently of those on the other, and it is very seldom that the same teeth of two gears will come into mesh on succeeding occasions. This practice, however, may be applied to the bevel gears of the driving shaft and rear axle and the pinions of the differential. As a further means of wearing the gears of the transmission to a perfect fit, the motor, transmission and driving shaft are installed in the chassis as shown in Fig. 41, and

the motor is run while the various speeds of the transmission are thrown into mesh in order to wear in every gear thoroughly. During this run an electric dynamometer, by means of which a variable load may be applied, is connected to the end of the driving shaft.

An ingenious device for testing the accuracy of gears is used in the factory of the Grabowsky Power Wagon Co., of Detroit. This consists of a standard having three pins or bearings set in it on which the gears of the transmission are placed as shown in Fig. 42, thus forming a replica of the planetary transmission as used in the car. The middle upright bearing is stationary while each of the other two is movable in a horizontal direction and is connected to a micrometer at either end of the base of the instrument. A master gear is set on one of these bearings, while the pinions to be tested are placed on the other two. When the two movable bearings have been so adjusted that all of the gears mesh perfectly, the readings of the two micrometers may be observed and the amount, in thousandths of an inch, by which the gears are "off" may thus be determined accurately. Certain limits of variation are necessarily allowed, but if any gear is below one or above the other, it is thrown out. Inasmuch as the distance between the centers of the gears must be constant in the transmission case, this instrument is useful in determining just what gears are acceptable without the necessity of installing them in the case.

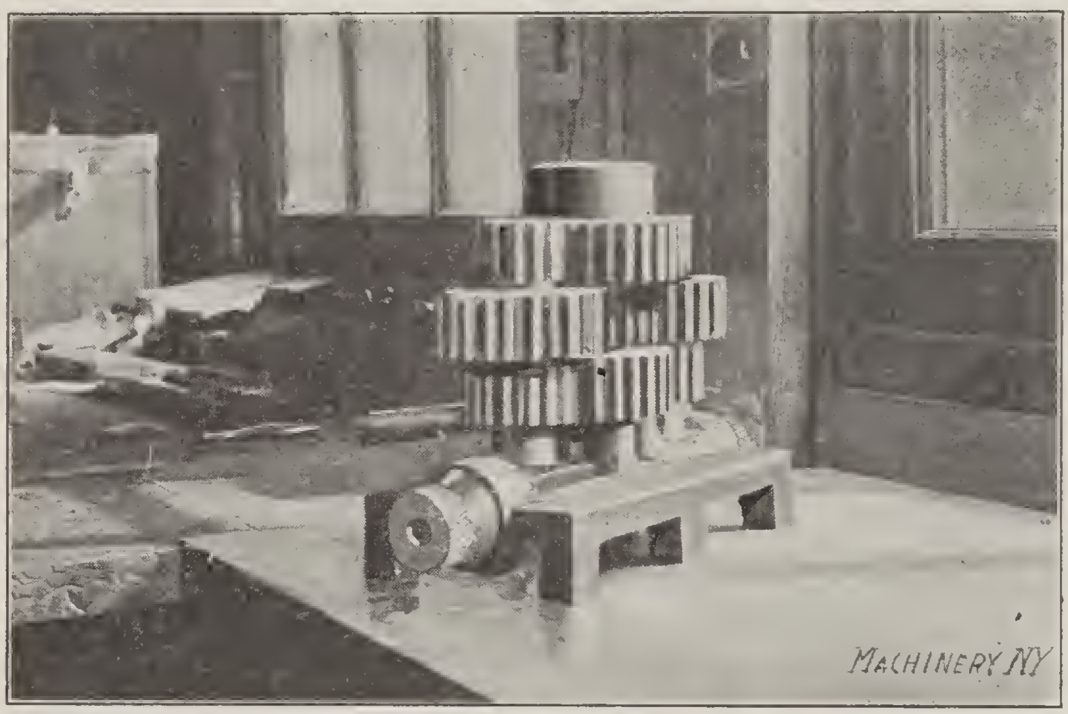

Fig. 42. Device for Testing the Accuracy of Gears

Many of the gears used in the forward end of the motor for driving the cam, pump and magneto shafts are made of manganese-bronze. The Premier car, however, made in Indianapolis, employs a laminated gear for the magneto shaft, built up of alternate layers of bronze and fiber. These layers are pinned firmly together and the gear is then cut by the usual methods. This makes an exceedingly quiet-running gear, as the layers of fiber or rawhide cushion the impact of the teeth as they meet, and the whirring or grinding sound familiar in many

all-metal gears is practically eliminated. It has been found by means of a series of exhaustive tests conducted in this factory that the silent running of this gear is brought about by a slight rounding or "bulging" of the face of the rawhide sections caused by the absorption of the lubricating oil in the pores of the fiber and the pressure against its sides. This, as mentioned above, effectually cushions the impact of the teeth, but if this bulge becomes too great, the teeth will not mesh properly, there will be a tendency to "jam" and more friction will be set up than would be the case were an all-metal gear used. Of course the wider these fiber sections are, the greater will be the bulge to each, and it has been found as a result of these experiments that laminated gears composed of layers of rawhide about 1/8 of an inch thick, alternating with bronze disks of the same dimensions, give the best service for this purpose. When sections of this thickness are used, a sufficient bulge is formed to cushion the impact satisfactorily, and yet this is not great enough to change the shape of the teeth materially. These experiments are still in progress at the factory in question in order the more accurately to determine other facts and figures concerning the best form of laminated gears, and this is only one of the many instances which give evidence to the fact that the American motor car manufacturer is now fully awake to the importance of paying attention to the most minute details of design.

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